ELECTRICAL ENGINEERING

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The Cover: North and West faces of the Materials Testing Reactor at the National Reactor Testing Station in Idaho, showing bridge leading from reactor top to control room. See page 955.

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Statements and opinions given in articles appearing in ELECTRICAL ENGINEERING are expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on controversial matters. Published monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

Headquarters
33 West 39th Street
New York 18, N. Y.

Editorial Offices
500 Fifth Avenue
New York 36, N. Y.

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VOL. 73 NO. 10

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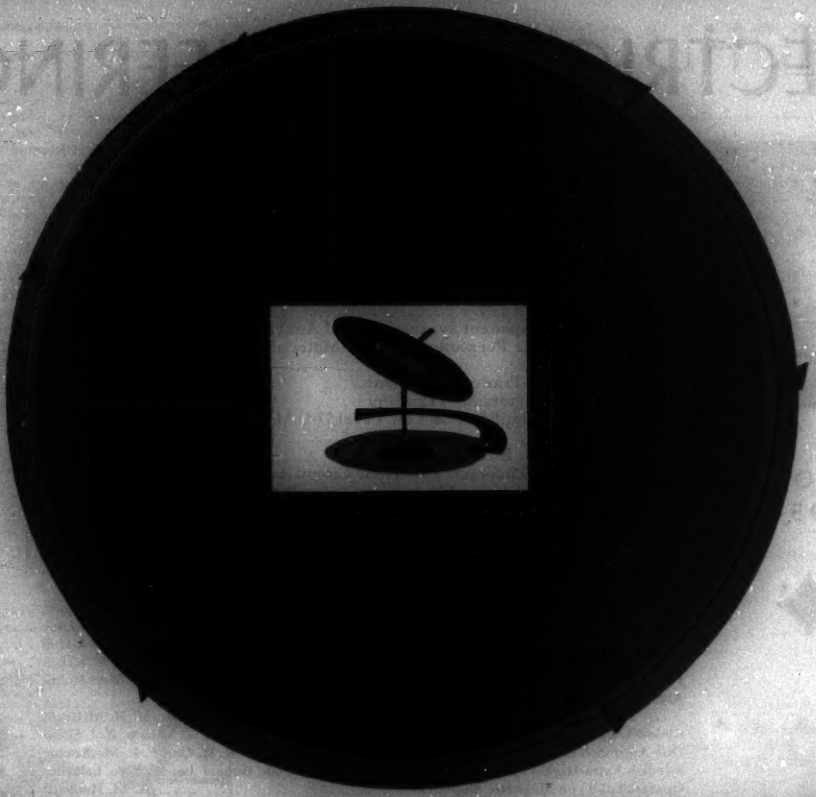

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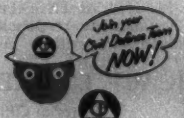

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HIGHLIGHTS.....

The Development of Managers. Men in high positions must get results through the co-ordinated efforts of others and they should aid others of managerial calibre to analyze themselves as to their qualifications for better jobs. Management-development programs are discussed in detail (*pp. 865–8*).

The Power Situation in Japan. Before the last war, Japan had 732 separate power companies, which were reduced to nine after hostilities had ended, each supplying a specific region. Future development projects are to be handled by a tenth company, which is government controlled (*pp. 870–2*).

Ten Founding Fathers of the Electrical Science—VII. The contributions of Karl Friedrich Gauss to mathematics, astronomy, geodesy, and electricity place him among the giants in the fields of the sciences (*pp. 874–5*).

A Symmetrical Component Synthesizer and Analyzer. This polyphase oscilloscope has verified the basic formulas for 3-phase 3-wire Y-connected unbalanced circuits. A simple method for experimentally determining the magnitudes of the positive and negative sequence components also was discovered (*pp. 887–91*).

Pulse Relaxation Amplifier: A Low-Level D-C Magnetic Amplifier. As a basically low-level signal device, several stages of pra can be used to amplify a low-level signal bringing it to the microwatt level. The concept of pra suggests a wide variety of new functions in such fields as optical pyrometry, precision calorimetry, spectroscopy, geophysics, meteorology, differential thermometry, or wherever extreme sensitivity is desired (*pp. 909–13*).

A Practice Course for Engineering Students. At the Massachusetts Institute of Technology, an elective subject, "Case Studies in Electrical Engineering Practice," includes the undertaking of one or more practical projects for which the members of the class have not had any previous preparation. The author was chosen as a visiting lecturer, and describes the investigations (*pp. 868–9*).

Mechanical Analogue for Solving Certain Power System Stability Problems. The model exploits the fact that, if a flywheel in equilibrium is disturbed, the equation of its subsequent motion is of the same form as that of a synchronous machine swinging about an infinite bus to which it is connected by a reactance, except that in the first case, minus synchronous speed has been impressed upon the system. Simple modifications allow for the inclusion of the effects of losses and line admittance. The 2-machine problem can be solved by the well-known method of resolving it into an equivalent single machine–bus bar system (*pp. 879–84*).

High-Speed Rapid-Transit Equipment. With the increasing traffic congestion in urban areas, the high-speed rapid transit operating on private rights of way is suggested as one of the best ways of alleviating the situation. The performance possible with a conventional rail rapid-transit system utilizing recent advances in propulsion is described (*pp. 898–901*).

Shaping the Characteristics of Temperature-Sensitive Elements. Types of temperature-sensitive elements are discussed, together with possible arrangements of shaping networks with two and three fixed resistances, the criteria for possible shaping arrangements, the synthesis of temperature-sensitive networks, and practical examples (*pp. 933–6*).

Small-Signal Parameters for Transistors. Although the commonly used sets of parameters are given brief coverage, the emphasis is placed on the fact that circuit performance of a transistor may be determined by any set of parameters supplied (*pp. 902–5*).

High-Coercive-Force Permanent-Magnet Materials and Their Application. In discussing permanent-magnet materials characterized by high intrinsic coercive force, design opportunities and problems involved in their applications are considered. Data is included on the ellipsoidal approximation method for estimating flux output of short magnets (*pp. 891–5*).

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Bimonthly Publications

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Economic Aspects of Using Electric Power for Waterflooding. An actual waterflood project already equipped for electrical operation is compared with one utilizing gas engines (*pp. 930–2*).

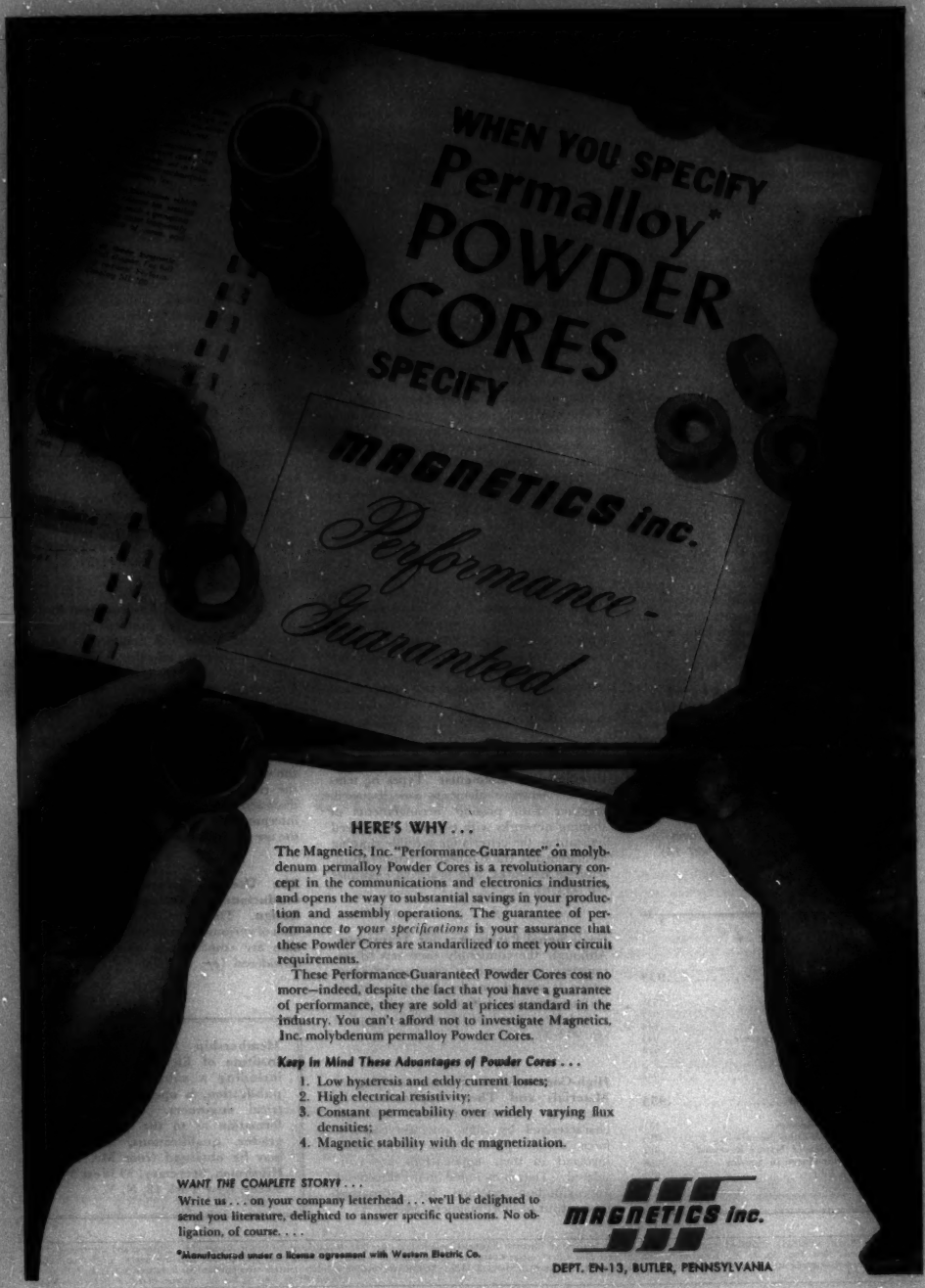
Air Ionization as an Environment Factor. This still unresolved problem is discussed in terms of ions and health, ion groups, ions and particles affecting health, ionization of the air, and experimental studies carried out (*pp. 916–20*).

Field Equivalence Theorems and Their Circuit Mathematics. The relationship of the equivalence theorems of field theory to the similar concepts of circuit theory is discussed. Emphasis is placed on the interpretation of impressed currents and on the use of perfect conductors (*pp. 923–7*).

The Use of Screen-to-Plate Transconductance in Multigrid Tube Circuit Design. The organization of the required data of various vacuum tubes and how these data are employed in circuit design are considered (*pp. 876–9*).

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. N. S. Hibshman, Secretary, 33 West 39th Street, New York 18, N. Y.

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices 200 Fifth Avenue, New York 36, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. October 1954, Vol. 73, No. 10. Number of copies of this issue 57,200.



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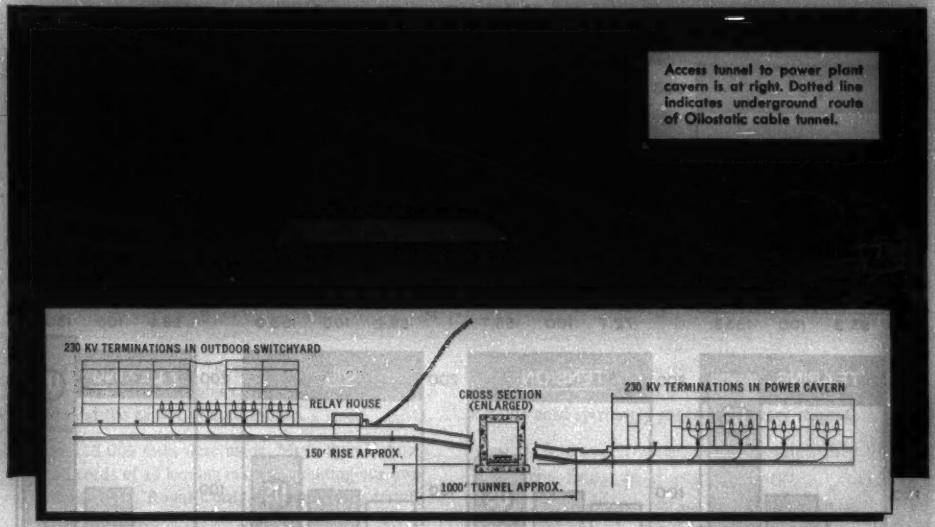
ANOTHER OKONITE FIRST:

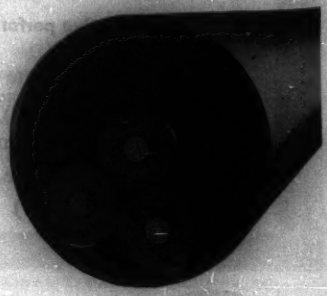
the first American-built 230 kv Oilostatic high-pressure oil, pipe-type cable system


Access tunnel to power plant cavern is at right. Dotted line indicates underground route of Oilostatic cable tunnel.
230 KV TERMINATIONS IN OUTDOOR SWITCHYARD
RELAY HOUSE
150′ RISE APPROX.
CROSS SECTION (ENLARGED)
1000′ TUNNEL APPROX.
230 KV TERMINATIONS IN POWER CAVERN

Schematic Cross-Section of 230 kv Oilostatic Cable System Cubatao Underground Station, Sao Paulo, Brazil.

Okonite's leadership in the development of high-tension cables is again demonstrated by the manufacture of a 230 kv Oilostatic cable—the first American-built 230 kv high-pressure, pipe-type cable system. This cable, recently shipped, was ordered in March, 1951, for installation at the Cubatao Underground Power Plant of the Sao Paulo Light and Power Company Limited, Sao Paulo, Brazil.

The underground power plant, utilizing a hydrostatic head of 2,300 feet, is located in a cavern 600 feet inside a mountain. Four Oilostatic circuits of single conductor, 500 MCM, 0.835-inch paper-insulated, shielded, D-shaped copper wire armored cables will carry the output of the four 65,000 kw generators being installed. A separate tunnel from the power plant to the switchyard is provided for the cable circuits and the control cables.

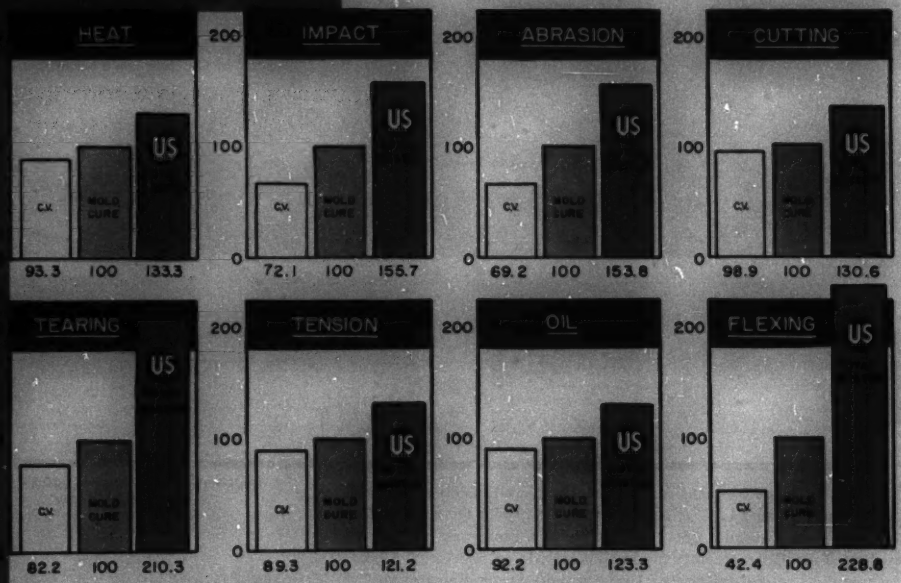


Oilostatic high-pressure oil, pipe-type systems are self-supervising, easy to install and require negligible maintenance. For complete installation and operation information, write to The Okonite Company, Passaic, N. J.

OKONITE OKONITE SINCE 1878 ***insulated cables***

2591

New U.S. ROYAL outperforms,



Comparative performance of portable cords related to major life factors.

Graphs illustrate the outstanding superiority of new U. S. Royal Master Cord—over the average of molded cords and the average of short-lived continuous vulcanized cords of other makes—on every major life factor. (Average of other molded cords is rated at 100%.)

US RUBBER

UNITED STATES

ELECTRICAL WIRE AND CABLE DEPARTMENT

Vol. 73
1953

MASTER portable cord *outlasts all others!*

Comparative tests show U. S. Royal Master gives $1.88 in value for every $1.00 spent — almost *twice* the service value of the average of other molded cords!

Two years ago, "U. S." engineers began a *complete reexamination* of portable cord construction, service life, and the causes of cord failure.

Over 10,000 tests were made. More than a thousand cords of all leading makes, including our own famous U. S. Royal Cord, were analyzed, tested, and compared.

Every life factor was considered and carefully evaluated, alone and in its relation to overall cord performance and service life.

Backed by 64 years of experience in the manufacture of electrical wire and cable, U. S. Rubber engineers then translated their findings into an entirely new portable cord, designed to surpass any other previously made.

Extensive tests, both in the laboratory and in outside plant installations have proved this new portable cord startlingly superior in every respect!

New U. S. Royal Master is unquestionably the finest cord you can buy!

From every standpoint, as the charts at left illustrate, new U. S. Royal Master is a finer, more durable cord—actually gives 88% longer life than the average of competitive molded cords—far longer than *any* other cord—surpassing even a hypothetical cord incorporating the best features of all those tested!

Far greater value, too! In spite of almost doubled service life, this great new cord is in the same price category as other molded cords—giving you $1.88 in cord value for every cord $1.00!

Prove to yourself the outstanding superiority of new U. S. Royal Master Portable Cord — in both service life *and* economy! Get in touch with your "U. S." distributor today!

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Power

Many utilities discover new economies with standardized designs... lower initial cost, shorter shipment, easier and faster installation

ALLIS-CHALMERS
POWER
Transformers

Three Purchasing Case Histories Tell Actual Dollar Savings Possible

1 **A MIDWEST UTILITY SAVED** $6,065.00 on one purchase of an Allis-Chalmers standardized unit on which it was possible to choose a different rated high voltage. For years this utility had purchased transformers with rated high voltage 66,000 delta and four 2½% full capacity taps below normal. By rating a standardized unit with high voltage of 62,700 and full capacity taps of 66,000-64,350-61,050 and 59,400 — a standardized unit was purchased at an approximate savings of 7%.

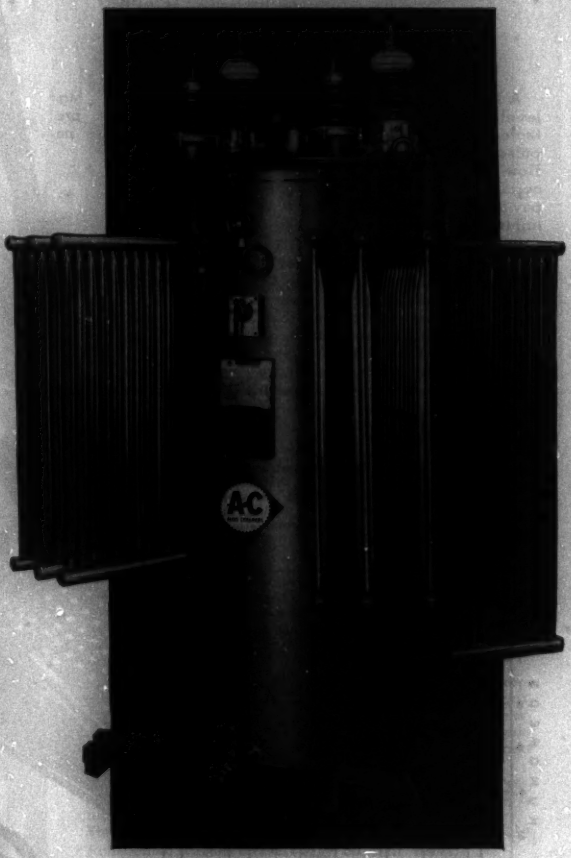
2 **AN EASTERN STEEL COMPANY SAVED** $1,920.00 with an Allis-Chalmers standardized unit. The new transformer, high voltage 67,000 volts, low voltage 7200 volts, will operate at 6900 volts at slightly reduced kva. This makes possible operation in a bank with an existing 6900-volt transformer. This customer foresees even greater savings when more standardized units are purchased.

3 **A SOUTHERN UTILITY SAVED** $1,557.00 by purchasing Allis-Chalmers standardized power transformers. It was found that three 1667-kva single-phase transformers rated at 13,200 voltage delta with two 2½% full capacity taps above and below normal to low voltage 2400/4160Y could be paralleled satisfactorily with existing non-standard transformers rated 1667 kva having a high voltage of 13,200 delta and taps at 12,540-12,210-11,880 to low voltage 2300/4000 wye (the transformer to be over-excited for 2400/4160 wye output).

ALLIS-

Transformers

Allis-Chalmers standardized design power transformers offer utilities attractive savings in time and money compared to special designs. Standardization eliminates or reduces engineering and manufacturing time, results in savings up to 8% of the total cost of a transformer. Delivery can be made faster than with special transformers. Installation is simplified by standardized location of accessories. If certified drawings are required, they can be obtained immediately in many cases.



Other Features Available

Manufactured in accordance with NEMA and ASA C57.12a Standards, these transformers are available in ratings up to 5000 kva single phase and 10,000 kva three phase. Considerable flexibility is available too. Other features include variations in primary voltages, junction boxes, different types of oil preservation, as well as other mechanical and electrical features.

It will pay to get complete details on savings made possible by Allis-Chalmers standardized transformers. Call your nearby A-C district office or write Allis-Chalmers, Milwaukee 1, Wisconsin, for more information.

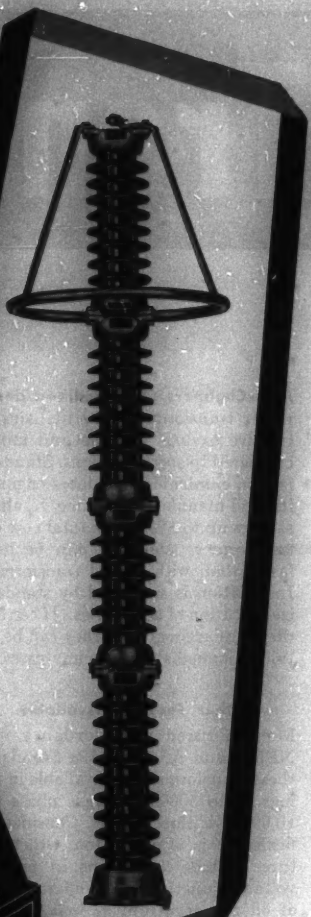
A-4429

A-C ALLIS-CHALMERS

CHALMERS

the most important arrester characteristic is

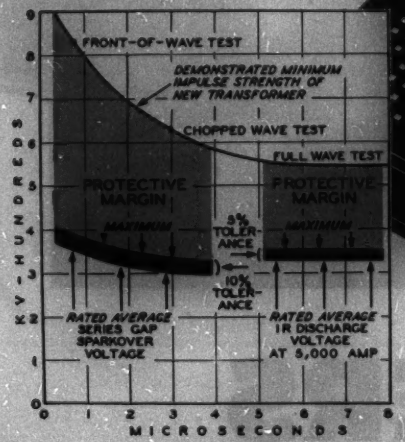
FIGURED IN DOLLARS



A lightning arrester functions at a given voltage level below the point of possible damage to protected apparatus. This point is the minimum impulse insulation level, or BIL of the equipment. How much "spread" or Protective Margin does a certain lightning arrester provide? What do you pay for it? In simple terms, this is the story of *any* lightning arrester.

What is the story of the O-B Thorex? It's just as simple and direct. First: The Thorex is rated in terms of MAXIMUMS, namely, with full tolerance applied to average listed values, so that *every* arrester is as good as, or better than stated. Second: Protective Margins are figured, conservatively, between this MAXIMUM point and equipment BIL. Third: You get substantially more Protective Margin, per dollar, when your apparatus is guarded by Thorex.

*Protective Margin, as illustrated in this typical application curve, is that zone existing between MAXIMUM arrester protective rating (tolerance added to average rating) and minimum insulation strength of equipment.



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MANSFIELD OHIO, U.S.A.

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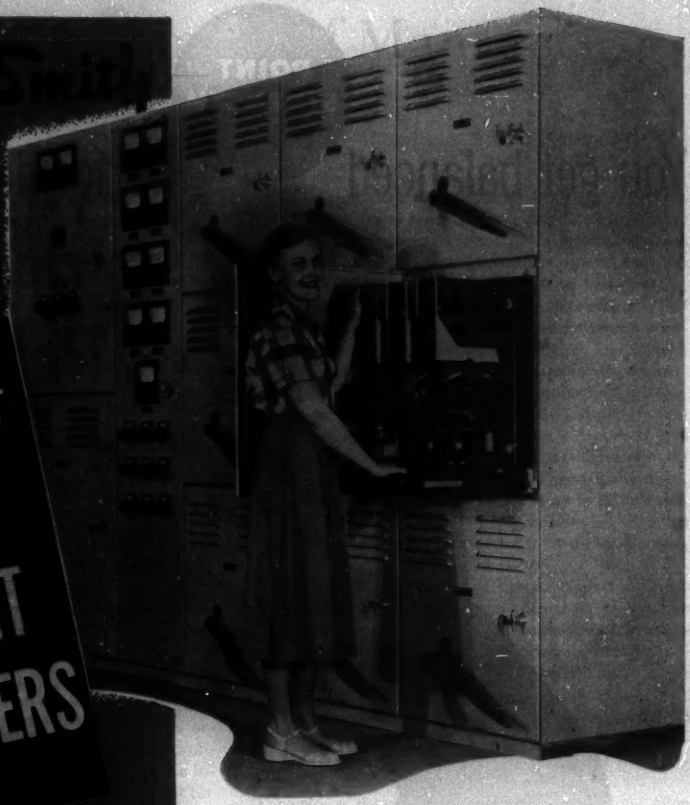
Roller-Smith

DRAW-OUT
AIR
CIRCUIT
BREAKERS



This typical Roller-Smith low voltage (600) switchboard . . . a main 2000 ampere electrically operated breaker with HD50 feeder breakers . . . is an all draw-out type. Hinged instrument panels and indicating instruments make it easy for the "Boss" to determine load condition of any breaker . . . instantly.

Draw-Out is "tops" for safety and convenience . . . like keeping your circuit breakers in roller bearing file drawer cabinets. Your own engineer appreciates its advantages . . . and your electrical contractor can make the installation with all circuit breakers removed and stored in a safe, clean place during placement of the switchboard.

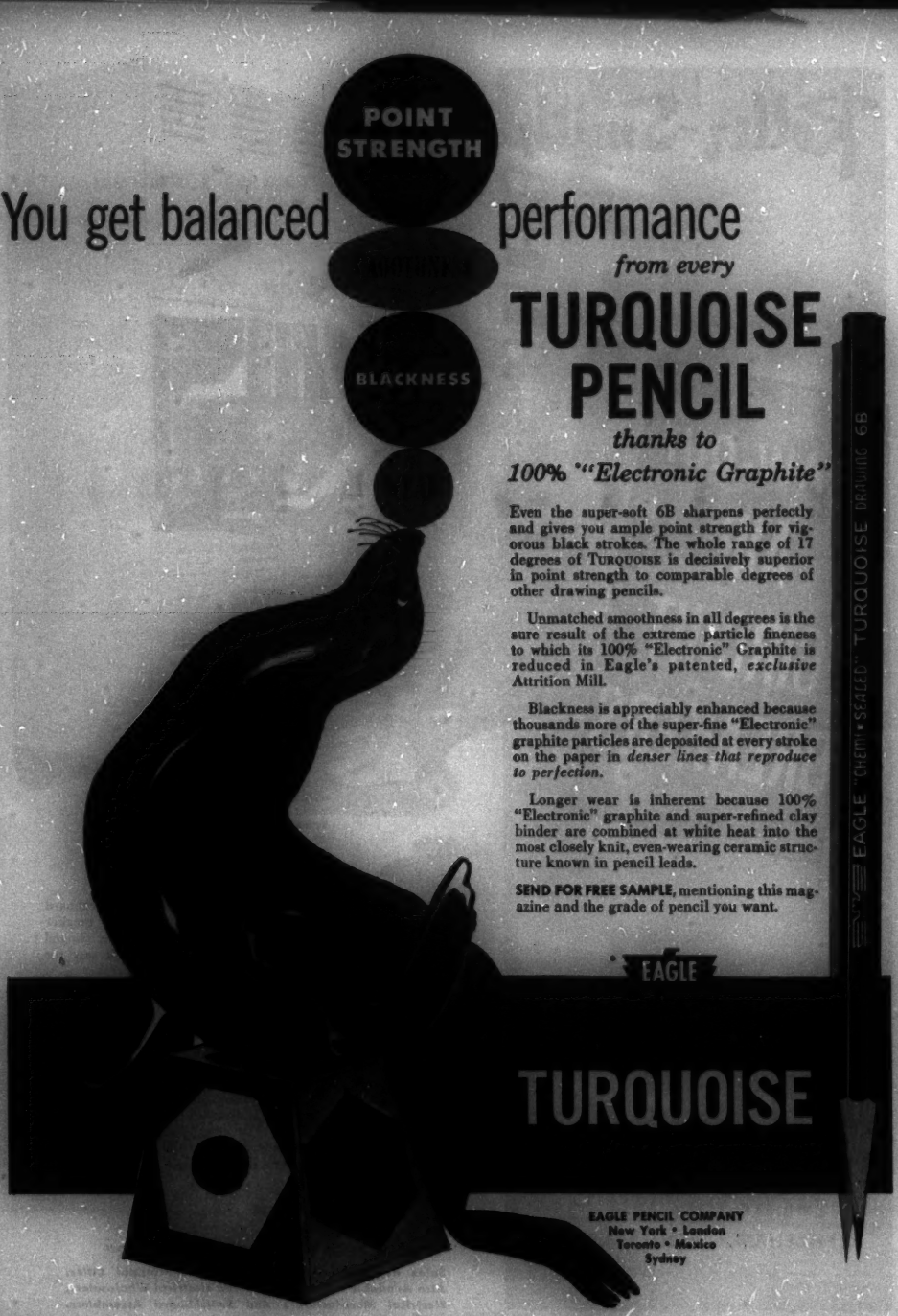
Your plant engineer and maintenance men know the advantages, too . . . of Roller-Smith draw-out air circuit breakers . . . they're fully interlocked.

The presence of the young lady attests to the ease with which Roller-Smith circuit breakers ride on their tracks.

Roller-Smith
ELECTRICAL SWITCHGEAR

"SEE YOUR ELECTRICAL CONTRACTOR"

Sales Representatives Located In All Principal Cities. Also Available Through Authorized Electrical Wholesalers, Electrical Manufacturers And Switchboard Assemblers.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BLACKNESS
You get balanced performance
from every
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The Development of Managers

R. H. DeMOTT

It is wise to have a management-development program in any organization which gives thought to its future. Engineers who attain managerial status should realize they must forego thinking as specialists and enlist the aid of those through whom they can get things done. This shift in thinking is vital.

THE DEVELOPMENT of managers among engineers is a logical extension and the application of those attributes which Alfred Douglas Flinn outlines in his splendid item in the *Encyclopaedia Britannica*. Under the heading, "Engineer, Professional," Flinn states:

"...Qualifications include
intellectual and moral honesty,
courage, independence of thought,
fairness,
good sense, sound judgement,
perseverance, resourcefulness,
ingenuity,
orderliness, application,
accuracy and endurance.

"An engineer should have ability to observe, deduce, apply, to correlate cause and effect, to co-operate, to organize, to analyze situations and conditions, to state problems, *to direct the efforts of others*. He should know how to inform, convince and win confidence by skillful and right use of facts. He should be alert, ready to learn, open-minded, but not credulous. He must be able to assemble facts, to investigate thoroughly, to discriminate clearly between assumption and proven knowledge. He should be a man of faith, one who perceives both difficulties and ways to surmount them. He should not only know mathematics and mechanics, but should be trained to methods of thought based on these fundamental branches of learning. Organized habits of memory and large capacity for information are necessary. He should have extensive knowledge of the sciences and other branches of learning and know intensively those things which concern his specialties. He must be a student throughout his career and keep abreast of human progress.

"Having been endowed more or less completely with qualifications and capacities requisite for a professional engineer and having developed them with the aid of educational and other institutions and contacts provided by civilized communities, the engineer is under obligation to consider the sociological, economic and spiritual effects of engineering operations and to aid his fellowmen to adjust widely their modes of living, their industrial, commercial and governmental procedures, and their educational processes so as to enjoy the greatest possible benefit from the progress achieved through our accumulating knowledge of the universe and ourselves as applied by engineering. The engineer's principal work is to discover and conserve natural resources of materials and forces, including the human, and to create means for utilizing these resources with minimal cost and waste and with maximal useful results."

And there you have it—a wonderfully complete word-picture of an engineer—and certainly an inventory of personal qualifications that any man in the top flights of management would be proud to possess. Theoretically, then, the engineering graduate who measures up to Flinn's estimate is certainly management timber. Coupled with this is the great need and high importance of the engineering sciences in industry.

Many factors, however, may mitigate against an engineer and he may never reach a management rank. The young engineer's first job will result probably in his assignment to a specific job, based on his educational background. When he is employed it is because he is needed and because he is important to the business.

He has greater importance, however, than merely as an individual who will apply his scientific knowledge in industry. This is especially true in those companies with promote-from-within policies, as we shall see later on.

The value of the creative scientist who works alone, often under severe handicaps, cannot be doubted. His accomplishments in every age and in every country, have been an inspiration—they will live forever in the history of man.

When we speak of engineers in industry, and of the men who will shoulder its management responsibilities, however, we think of individuals who are just a little different from the scientists who "go it alone."

TEAMWORK IN BUSINESS

A BUSINESS organization is made up of a group of people working together to accomplish predetermined goals and objectives. Its members must be able to work as a team. They must be as proud of the accomplishments of the group as a whole, as they are of their individual contributions.

While the interests of the individual may seem to be subordinated under this system, there is, in reality, sufficient latitude to satisfy the most rugged individualist. For the engineer of humility, courage, ability, determination, and exceptional human understanding, there are management opportunities unlimited.

The development of managers begins with the recognition of the principle that every man has within himself some

Revised text of a conference paper recommended for publication by the AIEE Committee on Management and presented at the AIEE Winter General Meeting, New York, N. Y., January 18-22, 1954.

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capacity to create, to accomplish, and to improve. It is more important than ever before for management to recognize the individual potentials of human beings. Failure to do this can only result in making more difficult the part that business must play in the areas within which it functions.

BUSINESS IS "PEOPLE"

Whatever the nature of a business, it is more than buildings, or equipment, or figures on a balance sheet. A company in the final analysis is people. People will give in accordance as they are encouraged to give. They will be loyal, if they are given loyalty. They will take action, if they are allowed the margin of human error by which each man can be secure in spite of his limitations and his mistakes.

Given a list of desirable management qualifications, such as those listed by Mr. Flinn, how does management go about a planned program of management development?

The first step, of course, since a business is presently staffed and manned, is an appraisal of those who are now in management positions.

In this connection, there are many management consultant firms available to those companies desirous of having professional assistance on management development. Their very effective procedure is to rate the qualifications, experience, skills, abilities, and characteristics required of an individual to fill the responsibilities of a specific job. Then, by very interesting oral, written, and psychological tests, they determine individual skills, abilities, and characteristics of the man holding the job. These are matched against the job requirements and it is pointed out clearly where the individual matches the requirements and where he falls short. We have done this very thing in our own organization, starting with the writer and covering something over 200 of our management group, and have found it of tremendous benefit and inspiration.

With this information at hand, management training for the development of leadership is largely a matter of arming a man with the knowledge he needs to handle his present job better, and to help qualify him for advancement until he eventually reaches the maximum level he is capable of attaining. What this eventual level of responsibility is will depend to a large extent on his intelligence, his personal characteristics and skills, his ability to deal with people, and his moral qualities.

MORAL QUALITIES IMPORTANT

This last is especially important. Studies of men in top positions have disclosed that they usually have a strong religious bent, high personal ethics, and an integrity which earns the trust of those whom they lead.

The management job today is becoming increasingly demanding. The rewards are attractive but usually they will not be won easily.

A management-development program is instituted to help a company succeed and prosper by helping the individuals who make up the company succeed and prosper. It is designed to help the individual grow and develop more surely and more quickly than if the matter were left to chance. The purpose of a successful program is humanistic, sympathetic, and constructive. It is a means, based on ability, for satisfying the human desires for opportunity, recognition, growth, and security, which are inherent in everyone.

HELP TO SELF-UNDERSTANDING

Centuries ago, Plato said, "Know thyself." His advice was sound then, and modern psychologists act on it today. By helping an individual to understand himself—his strengths and his weaknesses—it is possible to encourage him to be receptive to management-development activities which will help him grow.

The experiences of many companies have proved the soundness of the policy that whenever possible, management positions should be filled preferably by promotion from within. This is a very laudable policy and certainly no one can take justifiable exception to it if it is carried out properly. At the same time, it poses certain problems which must be met successfully if a business is to continue to prosper.

For example, the talent within the organization at least must be equal in ability or potential to that available outside. Also, if all or almost all promotion is to be from within, the selection of new employees becomes a matter of great importance. When you hire a young man you are not hiring only an engineer, an estimator, or a foreman, but you are hiring a potential president, vice-president, or division manager. You must feed good material in at the bottom if 10 or 20 years from now you are going to have good management leadership at the top. Thus, the problem of recruiting, selecting, and hiring new people for an organization must be regarded as being of even more importance than it has been in the past.

Management rapidly is becoming a profession backed up by a large body of organized knowledge. People are not born with a built-in fund of management knowledge, or even with management instincts, so it is pointless to talk about born management leaders. Management leaders must be developed if there is to be an adequate supply for our needs.

SUPERIOR HELPS PLAN FUTURE

Where a company has a management-development program in effect it will be found that the progress of the individual is the prime consideration. An individual's development program is planned jointly by himself and the head of his department, with the purpose of making it possible for the individual to develop to the full limit of his capacity.

A well-conceived management-development program has much to offer the able, ambitious man who wishes to get ahead. It will insure that his advancement keeps pace with his personal development. The value of such a management-development program is apparent. It is invaluable both to the company and to those individuals who wish to make progress.

Men in top positions must get results through the coordinated efforts of others. Their organizations are the tools with which they must work. They stand or fall on the results which they can obtain through their organizations.

Most people like to help others to succeed; they find personal pleasure in aiding others along the way.

These, then, are some of the basic philosophies and some of the steps which management is taking toward the development of managers. What about the engineer who aspires for management responsibilities—how can he evaluate himself, what actions can he take?

Let us go back for a moment to Flinn's list of qualifications. You will recall that the phrase stressed was, "to direct the efforts of others." This is the reason that we consider that qualification to be of special importance.

CHECK YOUR MANAGEMENT POTENTIAL

We all recognize that there must be management in every organized activity. Since the definition of the word "manage" is "to direct or conduct the affairs of"—right here we should ask:

How well do you manage yourself?
How well do you direct and conduct your own affairs?
How well do you inspire yourself into positive thinking?
How well do you lead yourself into sound aggressive and constructive action?

If you are satisfied with your own self-management, then:

How well do you manage one additional person?
How well do you direct and conduct the affairs of that one additional person?
How well do you inspire and lead him into sound, aggressive, and constructive action?

If you are now satisfied that you are doing well with your own self-management and the management of one additional person, then you possess the basic qualifications to manage 20, 200, or 2,000 people.

In management you must be willing to accept increasing responsibilities at all times; you must be ready to accept criticism and to recognize that you may not always do the best that can be done. You must be willing to analyze your shortcomings mercilessly, admit your mistakes, and try to do better in the future.

Formerly reference was made to a young engineer accepting his first job assignment; that he was employed because of his specialized knowledge and because he was needed and important to his employer.

In those companies that have management-development programs, such as the program we have in our own company, the young applicant would be given the same tests as those described for the men who presently hold management positions. For, as mentioned before, we are employing not only an engineer, but a potential candidate for a management position.

It is from this point, on through his business career, that the engineer's chances of reaching management responsibilities will be decided. The test basically determines his ability to make the shift from specialist to manager.

THE VITAL SHIFT

As a specialist rises from direct producer to manager, he must let go of his tendency to do things himself and start getting things done through others. This is not as simple as it sounds, for the difficulty of shifting one's emphasis from personal production to the production of others is great. It is a vital shift, however, and the ease and completeness with which it is made is one of the criteria of management effectiveness.

Up to a certain level, a man's progress on the job usually calls for increasing competence in a given field of specialization. There comes a time, however, when the only promotion left is to a position of management responsibility and the criterion then becomes managerial competence rather than technical know-how.

No longer is the vital question, "How much does he know, and how good is he in the application of this knowledge?" but rather, "How does he get along with other people, and how well is he able to direct, guide, lead, and inspire other people into doing things?" Too often the specialist has not been prepared for such a shift and for the new emphasis upon the nature of his responsibilities.

It is most unfortunate when specialists cannot or will not make this shift. There are those who drag their work right on up with them and continue to do what they should be delegating to others.

BE EITHER MANAGER OR SPECIALIST

There is the head of the engineering department who has failed to change from engineer to manager; the sales manager who always remains a salesman. It takes time and effort to keep abreast of a specialty. The manager who is doing a full-fledged job no longer has the time to continue working as a specialist. Management is now his specialty and he cannot be both an effective manager and expert specialist. If he attempts to do so, he deteriorates in each.

There is more to know about how to get engineers to produce than there is about how to produce as an engineer; about how to get salesmen to sell than there is about how to sell. It is highly important, when a specialist advances from producer to manager, that he recognize this distinction.

The shift must be a deliberate one. As the specialist looks back upon the nature of his past work, he can see it very clearly in terms of assignments, fundamentals, procedure, performance, and measurement of output. He must now look ahead to management and see just as clearly the nature of the responsibilities, the fundamental principles, the organized approach, the methods of management, and the measurements of its effectiveness.

It has been said that a good manager does not have to have detailed technical knowledge of what he is managing, because specialized skills are at his disposal in the form of staff. He supplements himself with people who have specialized technical knowledge.

Personally, we disagree in principle with this. The successful manager cannot dry up, he must continue to acquire as much knowledge about sales, production, finance, and all of the other phases of business, as he can.

BUSINESS BUILT ON SCIENCE

It is important to realize that the specialist who becomes a manager must do the same thing. He must relinquish the responsibilities of technical know-how and become a manager, while reinforcing his own skills with supplemen-

tary reading and study so that he can make fullest use of the services of specialists whose full-time responsibility is to give technical aid.

Engineering science is of highest importance in industry. While business is an art, it is, without exception, built around some science. At the hard core of every business there is a scientific principle. If industry were not to adapt the general laws of science, the result would be chaotic.

Inspiration can be found in the fact that engineers show more and more interest in their management status. There is no other group with better basic qualifications for management responsibilities.

So build for greater management responsibilities by asking yourself again:

How well do you manage yourself?

How well do you inspire yourself into positive thinking, and lead yourself into sound, aggressive, and constructive action?

How well can you inspire and lead 20, 200, and 2,000 persons?

It is our earnest hope that your future will be one of ever greater achievement and the attainment of management rewards ever in proportion to your best efforts.

A Practice Course for Engineering Students

ARAM BOYAJIAN
FELLOW AIEE

To better prepare the young engineers to make the transition from college to industry, new courses have been designed in which the students are assigned practical engineering projects in the fields in which they have had no previous course work.

THE TRANSITION from the classroom to industry is somewhat like that from the nest to the world. As anyone who has had an opportunity to watch a robin's nest has observed, in spite of the millions of years of the development of bird life, the transition from the nest to the world is rather traumatic to the youngsters. The transition from the classroom to industry is not so traumatic as cats and other predatory agents are absent, and in normal and prosperous times a friendly world of employers receives and coaches the graduates in their new professional life. The co-operative courses help this transition too, though they affect a small fraction of the graduates. Many graduates prefer those employers who offer more courses, so that their transition will be more like that from one school to another.

No matter in what form the transition takes place, many successful engineers will testify that they have had to acquire many subjects by themselves. There are examples of an erstwhile electrical engineer heading a chemical laboratory, a civil engineer in charge of an electrical department, a power option man developing electronic controls, etc. One will also hear the failures complain that they missed excellent opportunities because they had not had this or that course in college.

Since the engineer has to acquire many subjects by himself, and even add new knowledge to the old, would it not be a good plan to give him some experience in this kind of learning before he leaves school? It could be made very realistic by assigning him an engineering project in a field in which he has had no course.

COURSE IS ORGANIZED

AT the Massachusetts Institute of Technology, there is an elective subject listed in the catalogue as "Case Studies in Electrical Engineering Practice." Each term it is taught by a visiting lecturer from industry, who may organize the course in his own manner. It is not to be a formal lecture course, nor is it to be a recitation course based on a textbook, though the group would meet regularly.

It would include one or more engineering projects for which the members of the class would be individually responsible and for which they would not have had any previous preparation. It would be an exercise in how to break into an unfamiliar engineering field and take responsible charge of a moderate portion of it. The class would have to master the technology of the project quickly, make the necessary surveys, tests, and other preparatory work, and prepare satisfactory design, specification, and appropriate report to the client.

Would the person conducting the course be prepared for it? Would he have designs, drawings, and specifications

Full text of a special article recommended for publication by the AIEE Committee on Education.

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ready in his files, having chosen for the project some work he had done before? In general, lecturers had undertaken subjects which had not been done before, choosing a problem which had not been previously solved. As the major purpose of this subject was not to impart more knowledge but to gain experience in the acquisition of knowledge under normal industrial conditions without a tutor, an instructor unfamiliar with the field of the project could set an efficient example to the class, as he works along with them. This would be difficult for the instructor.

The author was invited to take over the course for a term. The challenge was accepted, and plans were made. A project foreign to his field of interests was chosen, and the undertaking became an adventurous task in an altogether unfamiliar field.

The first project undertaken was the design of an air-conditioning unit for a moderately priced home and one suitable for mass production. The students were all electrical engineers, having studied thermodynamics but not psychrometrics.

TECHNOLOGY OF THE SUBJECT

An inquiry regarding the best literature on the subject brought in a list of about eight handbooks, guides, and other references. A careful examination of these showed that the American Society of Heating and Ventilating Engineers' guide gave the basic information on the theory and practice of air conditioning, including manufacturers' equipments. This book was adopted as the principal source book for the project, and a schedule was made up to cover the field in the available time.

COMMERCIAL PRACTICE

Since the group wanted to know the actual engineering practice of one or more companies operating in this field, a letter was written to each one of the four leading manufacturers asking for whatever engineering practice information he would care to provide which would be of help in this project. All were generous and furnished copies of the instructions they put in the hands of their own application engineers, which even included their survey forms. In addition, they provided catalogues of their equipment.

Discussions in the classroom unavoidably raised questions which this visiting lecturer could not answer. They were saved for a special session at which an air-conditioning specialist was invited to be present. The expert talked on his approach to the air-conditioning problems and the pitfalls to look for, with a generous question and answer period.

SURVEY

To choose a house for the project, a realistic answer was found in a new house which one of the professors had bought and in which he wanted to install air conditioning. Copies of the architect's drawings of this house were obtained for each student. The students also made visits to the house to study its orientation and exposures, the insulation of the walls and windows, shading from trees, advisability of using the nearby river water for cooling, etc. The capacity of the warm air heater and ducts were checked for the winter load, and the capacity of the ducts were checked for the summer load. With the help of a sun-angle calculator, some of the students figured the expected temperature curve for the warmest day in August. Outside venetian blinds and other shading means were considered to reduce the direct radiation through the big thermopane windows. Each student arrived at his own conclusion.

REPORT TO THE CLIENT

Each student submitted a report to the client on the results of his survey and his recommended equipment and costs, together with his reasons for the recommendations. They did not all recommend the same thing and there was considerable difference in the size of equipment. The conservatives, or majority, recommended the nearest larger available size, and the economical ones recommended the nearest available smaller size.

Credit for the course was given on the basis of two things: the report to the client and an examination in elementary thermodynamics and psychrometrics.

CONCLUSIONS

Although it is for others to evaluate what was accomplished in this course, a few conclusions seemed to be clear.

The interest of the students and the quality of their work and reports indicated that the idea is a sound one.

In a 1-term course, either one or two different projects could be undertaken, depending on the interest of the group as well as on the magnitude of the projects. In a 2-project course, the person in charge would provide some guidance in the first, and very little in the second.

A course of this type naturally calls for the application type of projects. Invention type of projects would require special talents, and research type of projects would tend to be duplication of the thesis type of activity. Such a course is likely to be beneficial to the majority of the students except those who intend to enter either teaching or a research laboratory.

Largest Network Calculator

A new a-c network calculator was recently put into service by the Franklin Institute in co-operation with seven major power companies. The utilities will use this modern computing device to help solve many complex problems.

The power companies involved in the joint venture are: Atlantic City Electric Company, Delaware Light and Power Company, Jersey Central Light and Power Company, Metropolitan Edison Company, New Jersey Power and Light Company, Pennsylvania Electric Company, and the Philadelphia Electric Company.

The Power Situation in Japan

W. W. LEWIS
FELLOW AIEE

After World War II Japan was divided into nine sections each with its power company. In September 1952 a tenth company, controlled by the government, was formed to develop those power projects needed for the country as a whole but which were beyond the means of the individual companies to build. Power from any developed projects will go to one or more of the nine companies to market.

PREVIOUS TO World War II there were 732 separate power companies in the four main islands of Japan, with a total generating capacity of about 4,650,000 kw. During the war the country was divided into nine regions, each with an electric power distributing company. Generation and transmission for the entire country was handled by one state-managed company, the Japan Power Generating and Transmission Company (Nippon Hassoden Kabushiki Kaisha).

During the war the power facilities suffered considerable damage, as shown in Table I.

Table I. Power Facilities Damaged During the War

Facility	Number	Rating of Damaged Equipment
Generating plants	hydro power 5 steam power 12	1,410,000 kw
Transformer substations	306	1,160,810 kw
Transmission lines	7,500 cases	
Distribution equipment		value 200,000,000 yen
Consumers' facilities	about 2,000,000 houses	

After the war the damaged equipment was rehabilitated or replaced, so that by 1949 the industry had recovered to the prewar level. Nevertheless, the industry was in bad shape, as most of the equipment was old and inefficient; wages were high; coal was scarce, poor in quality, and high in price; income was low, and the demand for power was increasing and insistent.

Before the war, coal was imported from Korea and Manchuria, and had a heat conten tof 6,000 to 6,700 kilograms per calorie (kg/cal) (10,800 to 12,100 Btu per pound). The outcome of the war cut off Korea and Manchuria as sources of coal supply, and the power industry had to depend on Kyushu coal with heat content as low as 4,000 kg/cal (7,200 Btu per pound). The use of this coal caused a great amount of ash and reduced the efficiency of the boilers 50 per cent or more. It was necessary for the thermal stations to supplement coal with auxiliary fuels, such as coal gas, heavy oil, and coal tar. Since 1950 the situation has improved somewhat, as coal of better quality is now available.

In February 1948, the Japan Electric Power Generating and Transmission Company (known as Nippon Hassoden) and the nine electric power distributing companies were directed to reorganize, under the provisions of the Law Concerning the Elimination of Excess Concentration of Economic Power. A Holding Company Liquidation Committee was formed, and Nippon Hassoden submitted a plan calling for a single company on a national scale to handle generation, transmission, and distribution. The nine electric distribution companies suggested nine different companies, each to handle generation, transmission, and distribution in its own region.

In order to reconcile the two plans, the government established the Electric Industry Democratization Committee, composed of 19 members selected from circles outside the government. In addition to the two plans mentioned, the Electric Industry Workers Union submitted a plan for a single company on a national basis for generation, transmission, and distribution, and the federation of Prefectural Governments submitted a plan for operation of the electrical industry by the prefectural governments (similar to our state governments).

The study was carried on for about 3 years, and finally on November 24, 1950, the government promulgated the Ordinance Concerning the Reorganization of the Electric Industry. In this ordinance it was decreed that the country should be divided into nine districts, each with a private electric power company to handle all features of generation, transmission, and distribution of power in its own district. On December 15, 1950, an administrative organ was formed, called the Public Utility Committee, and through the proceedings of this committee the nine power companies were formally set up on May 1, 1951.

The Law Concerning the Expeditious Development of Electric Power Resources was promulgated on September 16, 1952, and under this law a tenth company was established, namely the Electric Power Resources Development Company. The purpose of this company, controlled by the national government, is to develop those power projects that are needed for the economy of the country as a whole, but are too expensive or speculative to be considered by one of the nine private regional companies. Under the provisions of the law, the power developed by the Electric Power Resources Development Company will be turned over to one or more of the nine regional companies for marketing.

The author visited Japan in October and November 1953, under the auspices of the U. S. State Department and the Institute of Electrical Engineers of Japan (JIEE). He was also designated AIEE Lecturer to the JIEE by the AIEE Board of Directors. Japan is divided into nine JIEE districts, corresponding substantially to the 9 power regions shown in Fig. 1. The author lectured at each of the 9 cities indicated in Fig. 1 and in addition at Kyoto, on the general subject of power generation, transmission, and distribution in 1953.

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Fig. 1 shows a map of Japan divided into nine regions, each served by one of the private power companies. There are four islands, the largest Honshu, and three smaller ones. The island at the extreme north is Hokkaido, at the south and west is Shikoku, and at the extreme west Kyushu. On the main island it will be noted that power generation often takes place in one region, with distribution in an adjacent region. This is because these developments were made and the transmission lines were in service before the country was divided into regions. In such cases the entire development usually belongs to the region in which the power is distributed.

In Table II the names of the nine power companies are given, together with the number of power plants and their kilowatt ratings, for the year 1952.

Table II. Power Companies and Generating Capacity in 1952

Name of Company	No. of Plants	Rating of Plants, Kw
Hokkaido Electric Power Co.	58	351,380
Tohoku Electric Power Co.	232	836,336
Tokyo Electric Power Co.	252	1,829,338
Chubu Electric Power Co.	219	1,115,693
Hokuriku Electric Power Co.	99	404,496
Kansai Electric Power Co.	146	2,283,180
Chugoku Electric Power Co.	101	1,285,412
Shikoku Electric Power Co.	65	298,197
Kyushu Electric Power Co.	172	1,130,749
Total	1,344	9,534,781

The total capacity was divided, approximately 3,000,000 kw in thermal units and 6,500,000 in hydroelectric units. The capability of the plants in December 1952 was reduced to approximately 2,000,000 kw thermal and 4,800,000 hydro, because of poor fuel and low water conditions.

Beginning in 1953 the power companies embarked on an extensive development program, and it is expected that by the end of 1957 approximately 2,600,000 kw in hydro generators and 500,000 kw in thermal generators will have been added, making an approximate total installed capacity of 12,600,000 kw.

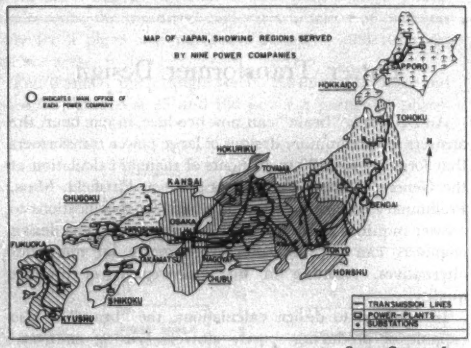
Toward the end of 1953, three of the power companies, Chubu Electric Power Company, Kansai Electric Power Company, and Kyushu Electric Power Company, completed negotiations with the International Bank for Reconstruction and Development, commonly known as the World Bank. Under the terms of the agreement reached, the World Bank loaned the power companies approximately $40,000,000, to be used for the purchase of steam boilers, turbine generators, and auxiliary equipment for thermal plants in the vicinity of Nagoya, Osaka, and Fukuoka.

In 1952 the actual energy supplied to consumers of all classes totalled 35,291,000,000 kwhr, and it is estimated that in 1957 the corresponding energy requirements will be 45,870,000,000 kwhr. In 1952 the deficiency of energy supplied in terms of the total energy required was 5.6 per cent. In 1957 it is expected that there will still be a deficiency of about 7.6 per cent, in spite of the large additions to be made to the plants in the 5 years 1953 to 1957 inclusive.

FREQUENCY AND TRANSMISSION VOLTAGE

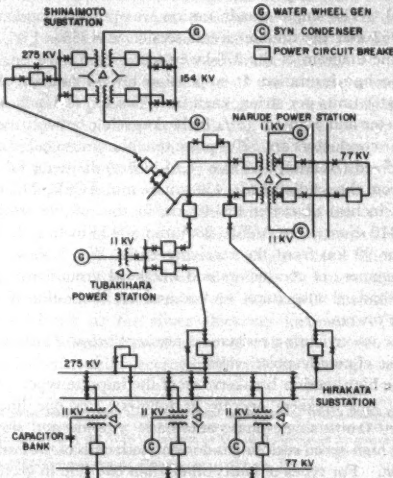
THE NORTHERN part of Japan, corresponding substantially to the regions served by the Hokkaido Electric Power Company, the Tohoku Electric Power Company, and the Tokyo Electric Power Company, is served at 50 cycles. The entire remainder, with the exception of a few isolated spots, is served at 60 cycles.

The prevailing transmission voltages are 77,000, 110,000, and 154,000 volts. In general, the systems operate with high resistance in the transformer neutrals, or with ground fault neutralizers (Petersen coils). This practice has been



Courtesy Commerce Japan

Fig. 1 (above). Map of Japan, showing regional areas served by nine power companies listed in Table II. The first word of power company's name is given on the map opposite the proper region, and is underlined. Circles indicate cities where main offices of power companies are located. Fig. 2 (right). One-line diagram of Shin-Hokuriku 275-kv Transmission System of Kansai Electric Power Company



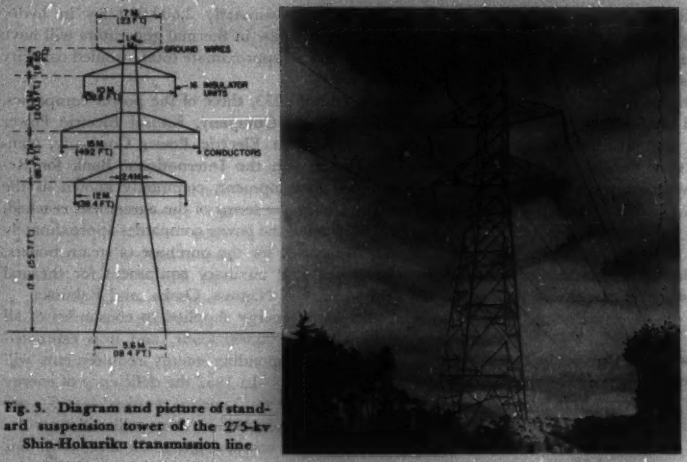


Fig. 3. Diagram and picture of standard suspension tower of the 275-kv Shin-Hokuriku transmission line

brought about by a ruling of the Government Department of Communications that not more than 300 volts may be induced on neighboring telephone lines when a fault occurs on a power line.

However, the new 275-kv Shin-Hokuriku transmission line of the Kansai Electric Power Company operates with the transformer neutrals solidly grounded. This line extends from Shinaimoto Substation on the Kurobe River to Hirakata Substation near Osaka.

The transmission line is single-circuit from Shinaimoto Substation to Narude Power Station, approximately 90 km (56 miles), then is double-circuit, with both circuits arranged vertically on the same towers, from Narude Power Station to Hirakata Substation, a distance of 230 km (143 miles). The single-circuit section was put into operation in 1952 and the double-circuit section in 1953. Fig. 2 is a 1-line diagram of the 275-kv system.

The line insulation at suspension towers consists of 16 insulator units per string, each unit 25.4 cm (10 inches) in diameter and 14.6 cm ($5^3/_4$ inches) spacing between units.

The conductors are 520 square mm aluminum cable steel reinforced (ACSR), 31.5 mm (1.24 inches) diameter for 190 km from the sending end; 430 square mm ACSR, 29.2 mm (1.15 inches) diameter for 40 km in the middle section; and 410 square mm ACSR, 28.5 mm (1.125 inches) diameter for 90 km from the receiving end. Fig. 3 shows the arrangement of conductors and overhead ground wires on the standard suspension towers, and an illustration of one of the towers.

The tower footing resistances are kept below 25 ohms by the use of counterpoise wires.

The high-tension breakers are of the impulse type. The relays and breakers operate as follows: For one line to ground faults, single-phase automatic tripping and single-phase high-speed reclosing is done at both ends of the faulted section. For types of faults other than one line to ground, 3-phase automatic tripping is done at both ends of the faulted line. After a suitable interval, 3-phase high-speed reclosing is done, provided the relays confirm that there is no fault on the parallel line.

The interrupting time of the impulse breakers is 3 cycles, and their minimum reclosing time less than 9 cycles. However, staged ground-fault tests on the line indicated that it was advisable to wait approximately 22 cycles before reclosing, in order to give the breaker time to deionize completely after the fault interruption.

Carrier-current relaying is used. Microwave comunication is used between principal stations, and the line is equipped with electronic fault locators.

All equipment for the line was built in Japan, including the towers, conductors, insulators, oil circuit breakers, transformers, synchronous condensers, static condensers, potential devices, and relays.

The Tokyo Electric Power Company is planning a 275-kv line for transmission from the Shinano and Nakatsu Rivers to Tokyo. Some sections of the line have already been built, including a few spans with double conductors in each phase, and are operating temporarily at 154 kv.

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Power Transformer Design

An electronic "brain" can now produce, in one hour, the answers for preliminary designs of large power transformers that formerly took 20 to 40 hours of manual calculation at the General Electric Company's plant at Pittsfield, Mass. Preliminary designs are used as a basis for specifications to answer inquiries from prospective purchasers. The design engineers can get accurate facts quickly on numerous alternatives, resulting in an improvement of product quality.

In addition to design calculations, the "brain" is also capable of producing speedy answers bearing on transformer operations, such as variation of hot-spot temperature under specified loading cycles and surrounding air temperatures.

The time and labor saving is accomplished by special engineering application of the card programmed calculator, an electronic computer of the International Business Machine Company.

Sheet and Plated-Metal Measurements

W. A. YATES J. L. QUEEN

IN THE FIELD of metal thickness and nondestructive plating depth measurement some need exists for a noncontacting instrument suitable for the continuous inspection of samples in motion. This article describes the basic operation of a direct reading instrument of this type for nonmagnetic metals.

The instrument, shown in block form in Fig. 1, is composed of an exciter, a phase-angle probe, and a high-input impedance phasemeter. The transducer, in proximity to the plate, has a secondary voltage consisting of two components, one due to the primary current and the other due to the eddy currents in the plate. The compensating transformer, isolated from the plate, has a secondary voltage determined by the primary current. With the mutual inductances of the two transformers equal, the phase angle, θ, between the compensating transformer output voltage, V_c and the difference output voltage, V_o, is equal to

$$\theta = \text{Arc tan } \frac{R_p}{\omega L_p}$$

where R_p and L_p are a shunt combination of resistance and inductance which represent the plate as far as its influence on the mutual inductance transducer is concerned. The quantities R_p, L_p, and θ are functions of the transducer coefficients, the excitation frequency, the resistivity and dimensions of the plate, and to a second order effect the transducer-to-surface spacing. The effect of transducer-to-surface separation may be practically eliminated over a reasonable range of operation by making the two mutual inductances slightly different so that with a given phase-angle probe the measured angle is a function of thickness only for a plate of a particular resistivity and sufficient surface area.

Fig. 2 shows phase angle versus thickness for brass and phosphor bronze at 25 and 100 kc for a particular phase-angle probe. The effect of distance was minimized for these readings by dynamically balancing the probe on a phosphor bronze sample 66 mils in thickness. Similar curves may be obtained for samples of other resistivity or thickness though, of course, the frequency or probe requirements might be different to allow the alternating field to penetrate the sample. Choice of operating conditions for a particular metal is fairly broad as can be seen from Fig. 2. At 8 mils thickness the relative sensitivity (the ratio of $\Delta\theta/\theta$ to $\Delta T/T$) varies from 0.83 at 25 kc to 0.93 at 100 kc for brass and from 0.65 to 0.90 for phosphor bronze.

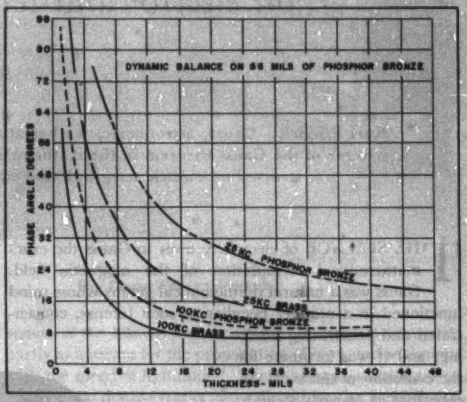

Fig. 2. Phase angle versus thickness for brass and phosphor bronze at 25 and 100 kc

This method also is applicable to the measurement of plating depth particularly when there is a wide disparity between the resistivities of the plating and base metal, for example, silver plated on nonmagnetic stainless steel. Here the phase angle is a more complex function since the thickness and resistivity of each metal is involved. Readings were taken on silver which was plated on a base material of 37 mils of type *321* stainless steel plated with 1 mil of nickel. For each frequency a single-valued function of thickness was obtained, decreasing from the base material angle at zero silver thickness to the reading for an infinite silver thickness as the silver thickness increased. (The effect of the magnetic layer of nickel was slight in this case though it might easily become intolerable for other grades of nickel.)

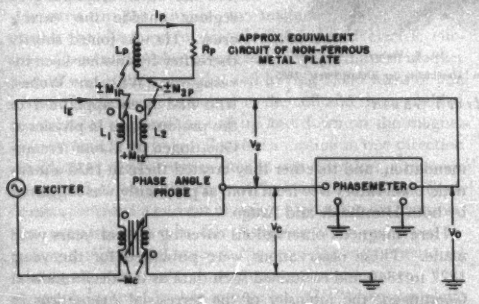

Fig. 1. Circuit for measuring phase angle of nonferrous metal plate

Digest of paper 54-173, "Sheet and Plated-Metal Measurements With a Phase-Angle-Type Probe," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 13-22, 1954. Published in AIEE *Communication and Electronics*, May 1954, pp. 138-42.

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TEN FOUNDING FATHERS OF ELECTRICAL SCIENCE

VII. KARL FRIEDRICH GAUSS

on electro- and terrestrial magnetism

BERN DIBNER
FELLOW AIEE

Karl Friedrich Gauss, astronomer, mathematician, and electrical experimenter, was the discoverer of the Gauss theorem in the mathematics of electricity. With Wilhelm Weber, he constructed an electric telegraph and extended data on terrestrial magnetism.

THE SCIENCE of electricity owes to Gauss the exact mathematical formulation of the magnetic field. Gauss was a natural mathematical genius whose mind functioned in a manner peculiar to such intense, concentrated and penetrating thinking, and it was fortunate for the evolution of electrical science that at an early stage in its development this fine mind turned to the resolution of its intricate problems.

Gauss was born in the humblest surroundings in Braunschweig, Germany. His unusual ability to solve complex mathematical problems at a very early age won for him the patronage of Ferdinand, Duke of Brunswick. At 18 Gauss had already evolved the method of "least squares," a device of great practical value to the surveyor and to the statistician. Another popular aid to the statistician, the rule of normal distribution of errors with its accompanying curve shaped like a bell, is familiar to all who handle variance and probability. Gauss was 19 when he discovered and proved the law of quadratic reciprocity. However, these accomplishments brought him little gain until at 25 he applied his mathematical principles in astronomy to the determination of the orbits of a family of asteroids—Vesta, Ceres, Pallas, and dozens of others. He invented the heliograph, an instrument of important military use, in which signals, in code, can be transmitted by reflecting sunlight from a mirror to an observer.

In electrical science Gauss is best known for his application of rigorous mathematical analysis principally to the field of terrestrial magnetism, a field that has become of increasing importance as the lanes of commerce multiplied over the surface of the globe. His first memoir on a theory describing the earth's magnetism, "*Intensitas vis magneticae terrestris*," was published in 1833. In it Gauss used measurements in absolute units to describe electric and magnetic quantities for the first time. He stated, "For the complete determination of the magnetic force of the earth in a given place, three elements are required: the declination, or the angle between the plane in which the magnet lies and a meridian; the inclination of its direction to the horizontal plane; and in the third place, the intensity." He thereafter showed how it was possible to separate the earth's magnetic field into two components—one originating inside the earth and the other originating in regions outside the earth's crust. He was joined shortly thereafter by another keen investigator, Wilhelm Weber, who had been appointed to the professorship in physics at Goettingen at Gauss' recommendation, and together they erected there in 1833 a magnetic observatory free from iron, as previously was suggested by both Humboldt and Arago.

J. K. F. Gauss W. E. Weber
From "Geschichte der Elektricitaet," 1885

Karl Friedrich Gauss

Here magnetic observations covering several years were made. These observations were published for the years 1827 to 1840 and contained such data as the declination at Goettingen, the intensity of the terrestrial magnetism in absolute terms, the variation of magnetic declination.

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There also was published data on the location and shift of magnetic poles and the axes and magnetic movement of the earth. Included in their publications were also charts showing the isomagnetic lines covering the known areas. Here too were centered the activities of an association formed by Gauss and Weber, called the *Magnetischer Verein*, in which other investigators made observations and contributed their data. Here was developed a sensitive declination instrument and the "magnetometer" which consisted of a magnet suspended by two wires (bifilar suspension), the deflection of the magnet being measured by the reflection of a beam of light from a mirror attached to the magnet upon a graduated arc. With this instrument the horizontal component of the earth's magnetic force was measured. At first this society was composed almost entirely of Germans, but later observers from many parts of Europe, extending as far south as Sicily, contributed their data taken on fixed term-days. Gauss analyzed the data and prepared two important memoirs as a result; one on a general theory of the earth's magnetism, the second on forces attracting in accordance with the inverse square of the intervening distance. With the magnetometer, Gauss first determined the intensity of the earth's field as indicated by the motion of a magnet suspended horizontally. The period of oscillation of the magnet in the earth's field first was measured and then the angle through which the needle of a magnetometer was deflected by the same magnet when placed a measured distance away. Both method and instrument are substantially those in use today. Gauss' connection with the observatory at Goettingen began in 1807 and continued until his death, a period of nearly 50 years.

From Geschichte der Elektricitaet, 1885

The Gauss-Weber telegraph

In order to communicate quickly between the iron-free magnetic observatory and the astronomical observatory also in Goettingen, Gauss and Weber connected the two observatories with an electric telegraph. This is one of the earliest uses (1834) of electric telegraphy. It consisted of a line of some 15,000 feet of wire and over this line impulses were generated in the circuit by magnetoelectric currents. Noting the discovery of Faraday of induced electric currents, Gauss and Weber arranged a large permanent magnet around which they placed a coil having 7,000 turns of fine wire. Handles were attached to the coil and these enabled the operator to move the coil up and down on the magnet or to remove it entirely. Because a motion in one direction would cause the current to flow in one direction, a reverser was added to keep the current flow unidirectional. Such motion provided a current of rather high value for transmission purposes but even faint impulses were registered by adding a mirror and scale to the receiving instrument and reading the movements through an optical magnifier. This telegraph inspired Weber to note in 1835 "when the globe is covered with a net of railroads and telegraph wires, this net will render services comparable to those of the nervous system of the human body, partly as a means of transport, partly as a means for the propagation of ideas and sensations with the speed of lightning." Gauss also proposed the idea of using the double tracks of a railroad for the transmission of signals and thereby electrically tying the network together. Steinheil tried to introduce this system on the Nuernberg-Fuerth line, but faulty insulation caused the project to fail.

Gauss' application of "absolute" units of length, mass, and time to magnetic fields prompted Weber to do the same to electric fields. Weber thereby determined, using the magnetic effects of an electric current, that this current will exert unit force at unit distance on one of Gauss' unit magnetic poles situated at right angles to the wire. In 1849 Weber began his investigations of electromotive force and of current and therewith evolved their units of measure. Having thus determined units of current and electromotive force Weber, by Ohm's law, found the unit of resistance.

For his contributions to our knowledge of terrestrial magnetism the International Congress of Electricians designated the value of intensity of a magnetic field by the term "gauss." A popularization of the term "degauss" occurred in World War II when measures were taken by the allied forces to neutralize the external magnetic field of a naval vessel and thereby to avoid triggering the magnetic mines set by the Germans. These mines were energized by the magnetic field of the steel hulls of ships not degaussed.

Gauss possessed the unusual power of devising dynamical models and drawing on analogies to demonstrate obscure physical relationships, particularly those in electrical science. Steeped in the severe discipline of mathematical thought he adhered to the practices of Archimedes and Newton in presenting for publication only completed works, simple and definitive, but omitting the steps by which his conclusions had been arrived at, a trait he had developed since boyhood. His contributions to mathematics, astronomy, geodesy, and electricity place him among the giants of the sciences.

The Use of Screen-to-Plate Transconductance in Multigrid Tube Circuit Design

K. A. PULLEN, JR.
MEMBER AIEE

The selection of triodes, and especially multigrid vacuum tubes, for specific applications may be systematized so that an immediate choice may be made of suitable tubes. The relation of screen-to-plate transconductance to the more commonly used tube parameters is indicated.

THE CONDUCTANCE contour technique* of circuit design provides a direct and rapid means of coordinated static and dynamic design of electronic circuits. It yields results in a form which enables the designer to tell by inspection whether the design will comply with design requirements or is marginal or unsuitable. Design rules based on the conductance technique enable the user to test alternate tubes for the tubes having unsatisfactory characteristics. The rules, however, do not enable one to reconsider the problem and directly select two or three tubes offering best opportunity for achieving the desired design.

One would think that the division of tube types into low, medium, and high-power groups would provide the separation required for adequate design. Unfortunately, such a tube type classification still leaves one with major selection problems not readily handled without additional design criteria or aids. Data on screen-to-plate transconductance offer one means of facilitating the final choices for tetrode and pentode tubes.

BASIC PHYSICS OF TUBE PERVEANCE

THE TERM perveance as applied to an electron tube is used qualitatively to separate tubes by their basic diode connection current-voltage characteristics. Tubes capable of developing large cathode currents within their electrode power dissipation ratings are classified as high-perveance tubes, and the rest as medium or low-perveance tubes. Actually, one finds that classification by perveance accomplishes little not already accomplished by the titles: high, medium, and low-power tubes. The classification of both systems in general tends to place high-power and high-perveance tubes together and similarly with the remaining classifications.

The problem of the selection can best be attacked by learning the basic significance of perveance of a tube in relation to its power-handling ability. Then the tube parameter or parameters best indicating the properties which need to be represented can be selected.

One may ask what is the basic difference between two tubes having major parameters identical with the exception of one single basic parameter? Several sets of tubes might be set up for comparison to aid in isolation of the appropriate parameter; for example, the *6SN7*, the *12AU7*, the *5687*, and the *12BH7* tubes as one comparison set. These double-triode tubes have approximately the same amplification factor. Otherwise they have a wide range of power-handling abilities. Consequently it can be said that the tube amplification factor is not of prime importance to power-handling ability. On the other hand, comparison of the *12BZ7* and the *12BH7* tubes (Figs. 1 and 2) shows the

* See list of references.

Full text of conference paper presented at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954.

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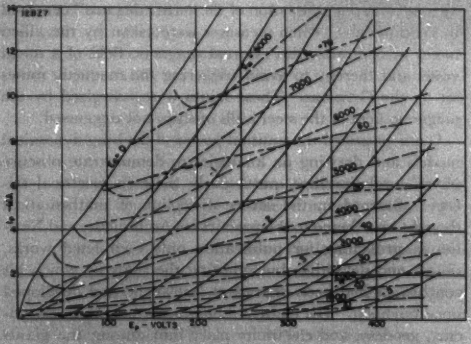


Fig. 1. Characteristic curves of the *12BZ7* tube

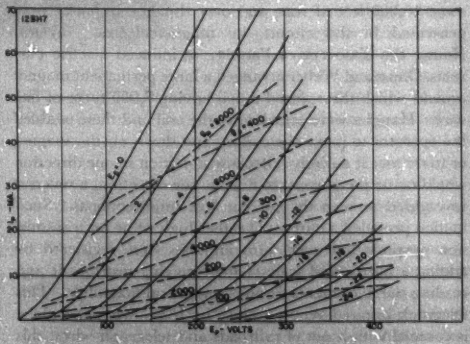


Fig. 2. Characteristic curves of the *12BH7* tube

former to have low power-handling ability, and the latter higher power-handling ability. The difference, as is now generally realized, is primarily one of plate conductance, since the transconductances of the two tubes are largely comparable.

Just how is the plate conductance difference able to produce such a large difference between two tubes which have nearly equivalent transconductance characteristics? The answer to this question is of fundamental importance to the understanding of the ability of a tube amplifier to handle high-power signals.

If one were to build an experimental triode tube on which the transconductance were fixed and the plate conductance variable, how would the characteristics of the tube change as the plate conductance was varied? Examination of the typical plate characteristic curves of the *12BH7* and the *12BZ7* tubes shows that the effect of increase of plate conductance is to cause a more rapid rise of plate current with plate voltage (higher perveance). As the plate conductance is increased more, bias contours appear near zero plate current. The tube requires more bias to cut off plate current. As either the plate supply voltage is increased or the plate conductance is increased, the total change of plate current available and the change of bias available in the tube increase.

In tetrode and pentode tubes a similar situation exists. In multigrid tubes, the plate voltage has relatively little effect on the plate current. Variation of the screen voltage applied to the tetrode or pentode tube quickly shows that the parameter in pentodes corresponding to triode plate conductance is screen-to-plate transconductance. As in the case of triode tubes, tetrodes or pentodes which control large amounts of current must either have a high screen-to-plate transconductance, or a high screen (and even higher plate) voltage. The correctness of the conclusion can be readily verified by examination of the screen characteristic curves of the *12BY7* and the *6BQ6* tubes (Figs. 3 and 4). Estimating the screen-to-plate transconductance along the zero bias line for these tubes gives approximate values of up to 500 micromhos for the *12BY7* tube and up to 2,500 micromhos for the *6BQ6* tube. Consequently, the current change capacity of the *6BQ6* tube is five times that of the *12BY7* tube. The bias range is correspondingly altered.

The next question to be answered is "How much of the current change capacity can be used successfully?" Here the question of plate and/or screen dissipation becomes important. The factor of importance with the *12BY7* and the *6BQ6* tubes is the plate dissipation.

Assume that the design for the use of the *12BY7* tube has shown that the *12BY7* design is marginal in operation. If the *6BQ6* tube is substituted for the *12BY7*, the change in plate dissipation capabilities would permit up to 70 per cent increase of static plate current. The tube inherently, however, is capable of five times the current change of the *12BY7*. Obviously the circuit should be redesigned to provide the maximum current change capabilities. Because the power-handling ability of the *6BQ6* is only 70 per cent greater than that of the *12BY7*, the full capabilities for apparent current change cannot be realized. The possible reduction of screen and plate voltages may make available up to $2^1/_2$ times the current change available in the *12BY7* tube.

A design can be altered by selection of a tube having the same screen-to-plate transconductance but higher plate dissipation. Such a change might be the substitution of a *6CL6* tube for a *12BY7*. The advantage gained is frequently of rather small value unless the actual increase in dissipation available is of the order of two or three times.

USING SCREEN-TO-PLATE TRANSCONDUCTANCE IN DESIGN

THE VALUE of screen-to-plate transconductance required of a pentode depends entirely on the signal characteristics required of a circuit. Any given type of pentode tube can be made to accomplish a moderate range of operations. Where design for reliability is required, one should establish a series of pentode tubes having screen-to-plate transconductance geometric ratios of two to four with respect to each other, and a gradually increasing power-handling ability as the screen-to-plate transconductance is increased. Then select the lowest screen-to-plate transconductance tube of the series capable of meeting distortion and power-handling

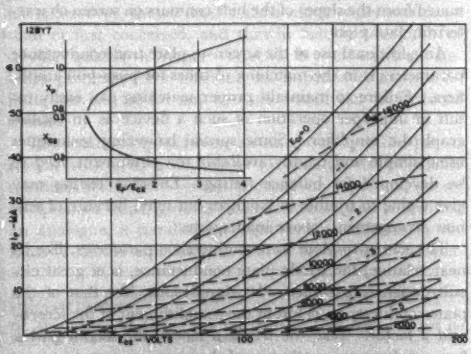


Fig. 3. Characteristic curves of the *12BY7* tube

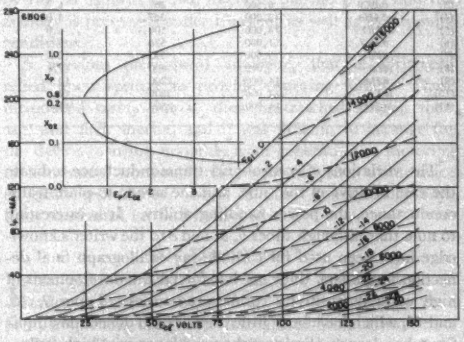
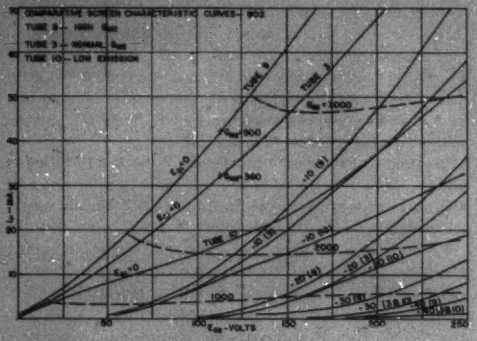


Fig. 4. Characteristic curves of the *6BQ6* tube


COMPARATIVE SCREEN CHARACTERISTIC CURVES—802
TUBE 9—HIGH
TUBE 3—NORMAL
TUBE 10—LOW EMISSION
TUBE 9
TUBE 3
TUBE 10
-10 (9)
-20 (9)
-30 (9)
-10 (3)
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quently, this article has been prepared to clarify the usefulness and importance of screen-to-plate transconductance as a fundamental parameter in circuit design.

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A Simple Mechanical Analogue for Solving Certain Power-System Stability Problems

ALLAN GREENWOOD

This simple device, useful in solving many system stability problems, gives a clear physical picture of the performance of a synchronous machine under steady-state or transient conditions. The model permits the derivation of predetermined swing curves similar to those of Summers and McClure and offers a quick method of finding critical switching and reclosing times. Probably damping forces like effects of governors and regulators can be simulated.

THE EQUATION of motion of a synchronous machine during transient phase swing conveys to the uninitiated little idea of the physical events occurring. The simple mechanical analogue described in this article was developed in the first instance as a demonstration piece to help students gain a real appreciation of the problem. Experiment and experience with the model have, however, shown that it has a much wider usefulness than at first conceived, and that in fact, it is capable of solving quickly a rather wide variety of transient stability problems for a machine, an impedance, and an infinite bus bar, or for any network which can be reduced thereto.

The relationship between an analogue and the parent system which it is intended to simulate is essentially mathematical. The system presents an equation, or set of equations which governs its performance, and in devising an analogue, a parallel is sought which conforms to the same or similar equations, so that in solving its own equation, the analogue solves also the corresponding problem in the system proper. In the case under review the analogue of the synchronous machine rotor is a flywheel, which is acted upon by forces corresponding to the electromechanical forces experienced by the rotor under running conditions. Sudden changes on the system which cause alterations to certain forces on the machine, are simulated by the adjustment of like forces in the model, so that the analogy is preserved under transient as well as steady-state conditions.

A previous mechanical analogue, that of Griscom,[1] relied upon springs to provide restoring forces. These introduced errors due to their unstretched length, their sag, and their inertia, and it was difficult to arrange for the device to swing smoothly from generating to motoring or conversely; nor could many types of system disturbance be easily reproduced. Most of these shortcomings have been eliminated in the flywheel model.

THE STEADY STATE

If an electrical source and link are interconnected in order to transfer energy from one to the other at a fixed frequency, the power transmitted for a given set of conditions depends upon the effective electromotive force (emf) at the sending and receiving ends, their mutual

A special article recommended for publication by the AIEE Committee on Transmission and Distribution.

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The author wishes to express his thanks to Professor J. C. Prescott for his advice while this article was being prepared and to the Sperry Gyroscope Company, Ltd., for its co-operation in supplying bearings for the flywheel.

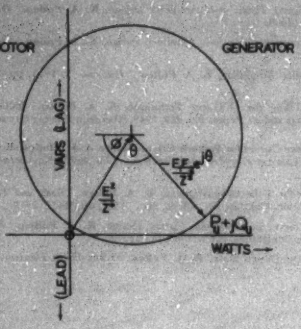

Fig. 1. Circle diagram for a series impedance link

phase angle, and the impedance of the link. The power may be expressed

$$Pu = \frac{D}{B} E_1^2 \cos(\beta - \delta) - \frac{E_1 E_2}{B} \cos(\beta + \theta) \quad (1)$$

being the real part of the vector power given by

$$Pu + jQu = E_1^2 \frac{\mathbf{D}^*}{\mathbf{B}^*} - \frac{E_1 E_2}{\mathbf{B}^*} \epsilon^{j\theta}$$

where $\mathbf{E}_1 = E_1 \angle \theta$, effective emf of the source (if the source is an alternator, $\mathbf{E}_1$ is its emf behind transient reactance), $\mathbf{E}_2 = E_2 \angle 0$, effective emf of the link, θ = phase angle between $\mathbf{E}_1$ and $\mathbf{E}_2$ in electrical degrees, $\mathbf{B} = B \angle \beta$, $\mathbf{D} = D \angle \delta$ are two of the complex hyperbolic parameters **A**, **B**, **C**, and **D** of the interconnecting network. If admittance in the interconnector is negligible, $D = 1$ and $\mathbf{B} = \mathbf{Z} = Z \angle \phi$, where **Z** is the series impedance to which the network reduces; thus equation 1 simplifies

$$Pu = \frac{E_1}{Z} \cos\phi - \frac{E_1 E_2}{Z} \cos(\phi + \theta) \quad (2)$$

Again, if circuit resistance is neglected, the expression for transmitted power is simply

$$Pu = \frac{E_1 E_2}{X} \sin\theta \quad (3)$$

Thus if the mechanical input to an alternator which is supplying an infinite bus bar through a pure reactance, is steadily increased, the corresponding increase in electrical output from the machine will be accompanied by an advance in the rotor angle θ in accordance with equation 3. If the interconnector possesses resistance, the power (or torque)/angle sinusoid will be displaced, the first term in equation 2 being a constant; whereas for a general network, Pu and θ will conform with equation 1.

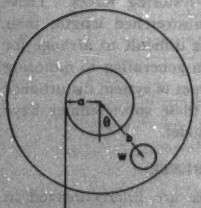

Fig. 2. Simplest form of the flywheel analogue

* The conjugate of the quantity.

Similar expressions to equations 1, 2, and 3 may be derived for the reactive volt-amperes transferred, thus permitting a graphical representation of events by means of a circle diagram.[2] Fig. 1 is such a diagram for a line without admittance; the co-ordinates of the tip of the vector $\frac{E_1 E_2}{Z}$, referred to the axes shown, represent the power and reactive volt-amperes being dispatched. Under steady conditions, therefore, the rotor is driven at synchronous speed by a constant shaft torque against the back torque of the load, which, in the simplest case considered, varies sinusoidally with the rotor angle measured from a synchronously rotating datum.

This property of preserving an equilibrium between a constant torque and one varying as the sine of the angle of rotation from some radius of reference, is possessed by a flywheel mounted with its axle in a horizontal position, having a constant torque applied by a driving weight, W, attached to a string about its shaft, and a counter torque provided by a riding weight, w, fixed near its rim, see Fig. 2. The torque Wa corresponds to the input of the prime mover, while the torque $wb \sin\theta$ represents the load torque of the alternator $\frac{E_1 E_2}{\omega X} \sin\theta$, ω being the angular velocity of the machine.

The analogue of the alternator and a series impedance line is shown in Fig. 3, together with its torque/angle curve. The addition of the weight W' is necessary to take cognizance of the constant term $\frac{E_1^2}{Z} \cos\phi$ in equation 2.

If W is progressively increased, the vector pointer indicated by the arrow in the diagram will trace out against appropriate axes a circle diagram like Fig. 1. However, should θ exceed $(\pi - \phi)$ the mechanical analogue then will become unstable, as would the alternator under similar circumstances, for it would then have passed its static power limit.

TRANSIENT CONDITIONS

In the event of a sudden change in circuit conditions causing a change in the output Pu from the alternator, or a sudden change of Pi, its input power, the existing equilibrium between these two quantities will be disturbed. Neglecting damping, the differential power so created will be accommodated by a change, positive or negative, in the kinetic energy of the rotor, and it will temporarily speed up or slow down, i.e., θ will alter. Whether it will attain a new steady running condition will depend upon the violence of the disturbance. The literature is freely endowed with analyses of the subsequent electromechanical derangement (see, for example, references 2, 3, 4, and 5). In developing the flywheel analogy in this article, such considerations will, therefore, be kept to a minimum. For the ensuing brief treatment, which for the moment will be confined to the study of a machine, impedance, and an infinite bus, it will be assumed that E_1 and E_2 are constant, that Pu can be calculated from the steady-state conditions, and that the mechanical angle of the alternator rotor coincides with the electrical phase of the voltage

behind transient reactance. All forms of damping will be neglected temporarily.

Following the disturbance the swing equation is of the form

$$\frac{M d^2\theta}{dt^2} = \Delta P = Pi - Pu \tag{4}$$

where M is the inertia constant of the alternator and its prime mover. If θ is measured in electrical degrees, M will be in joule-seconds (or megajoule-seconds) per electrical degree. It is perhaps more convenient to use per unit values, then $M = \frac{H}{180f}$ where H is the energy stored per unit rating of the machine and f is the frequency. When the impedance between E_1 and E_2 consists of reactance only, equation 4 may be expressed

$$\frac{M d^2\theta}{dt^2} = Pi - \frac{E_1 E_2}{X} \sin\theta \tag{5}$$

Even in this simple case the formal solution for θ as a function of t is complicated, and iterative or step-by-step methods are usually employed; graphical solutions have also been developed.[6,7]

If the flywheel model referred to suffers a similar disturbance, it will commence to swing in like manner, and if certain conditions are fulfilled, will follow precisely the motions described by the machine. Clearly, there must be some corelation between the inertias of the model and the machine. To be more exact, their natural periods of oscillation must be identical.

Considering the flywheel, Fig. 2, unloaded, i.e. with W removed, its equation of motion following a disturbance will be

$$\frac{J d^2\theta}{dt^2} = wb \sin\theta \tag{6}$$

where J is its moment of inertia. For small swings (θ measured in radians) its period of oscillation will be

$$\lambda = 2\pi \left(\frac{J}{wb}\right)^{1/2} \tag{7}$$

For the alternator, from equation 5

$$\lambda = 2\pi \left(\frac{MX}{E_1 E_2}\right)^{1/2} \tag{8}$$

For the analogy to be complete these times must be the same

$$\text{i.e. } \frac{J}{wb} = \frac{MX}{E_1 E_2} \tag{9}$$

Previously a relationship between $\frac{E_1 E_2}{X}$ and wb has already been established in connection with steady-state conditions. Thus equation 9 permits the selection of J for any prescribed value of M. In practice, when using a model to make a study the reverse procedure is followed. The right-hand side of equation 9 is fixed by the problem so, starting with a given flywheel of fixed inertia, the correct maximum torque to be exerted by the riding weight is fully determined. Alternatively, the natural period of the machine in the problem can be calculated, and the weight w adjusted experimentally to give the same period in the model.

The values so found for w and W may be inconvenient. For example, their masses may make an appreciable contribution to the inertia of the system, a point which raises difficulties when mid-swing switching operations are to be simulated. However, a little consideration will show that w and W may be reduced in the same proportion without altering the mode of a given swing but merely

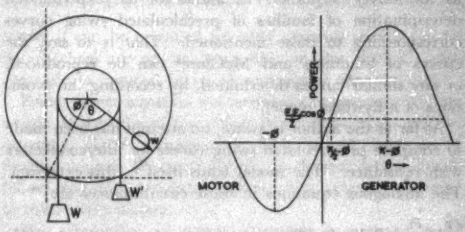

Fig. 3. The analogue of the series impedance link with its power/angle curve

changing the time scale of the flywheel swing curve with respect to that of the actual machine. Equation 7 shows that

$$t \propto \left(\frac{1}{w}\right)^{1/2}$$

It is perhaps worth noting that the theory propounded here is in no way viciated by the presence of resistance in the interconnection, nor indeed if the link forms a general network, though, of course, the weights may express quantities of greater complexity.

APPLICATION OF THE FLYWHEEL MODEL TO THE FORMULATION OF PRECALCULATED SWING CURVES

The scope of the flywheel analogy is broadened by introducing the concept of a "generalized swing equation" in terms of a modified time as used by Summers and McClure.[8] Equation 4 may be rewritten

$$\frac{d^2\theta}{d\tau^2} = \frac{Pi}{M} - \frac{P_{max}}{M} \sin\theta$$

Making substitution, $\tau = \left(\frac{P_{max}}{M}\right)^{1/2} t$, and $P = \frac{Pi}{P_{max}}$

$$\frac{d^2\theta}{dt^2} = P - \sin\theta \tag{10}$$

This equation is quite general, being independent of M and the electrical constants of the circuit. There are an infinite number of solutions depending upon the ratio of the power input Pi to the maximum power P_{max} and upon the initial angle θ_0. Summers and McClure[8] have plotted families of such curves solved by intigraph, in which each group is appropriate to specific value of θ_0,

the individual curves representing different values of P within the likely range to be encountered.

For the model under transient conditions

$$\frac{Jd^2\theta}{dt^2} = Wa - wb \sin\theta \tag{11}$$

this leads to a similar general expression in terms of τ

$$\frac{d^2\theta}{d\tau^2} = \frac{Wa}{wb} - \sin\theta \tag{12}$$

(It is clear from equation 9 that τ will have the same value as formerly.) Equation 12 allows for the experimental determination of families of precalculated swing curves corresponding to those mentioned. That is to say, the curves of Summers and McClure[8] can be reproduced, or any similar curves determined, by recording the evolutions of a flywheel model.

As far as the author is aware, no attempt has been made to compute precalculated swing curves for interconnectors with resistance. The model lends itself to this extension. The analogous equations in these circumstances are

$$\frac{d^2\theta}{d\tau^2} = \frac{Pi}{P_{max}} - Pc + \cos(\phi + \theta) \tag{13}$$

(To be strictly accurate, equation 13 should be expressed in torques rather than powers.)
and

$$\frac{d^2\theta}{d\tau^2} = \frac{Wa}{wb} - \frac{W'a}{wb} + \cos(\phi + \theta) \tag{14}$$

where now $P_{max} = \dfrac{E_1 E_2}{Z}$, and $Pc = \dfrac{E_1}{E_2}\cos\phi$.

A new parameter, $\phi = \tan^{-1}\dfrac{X}{R}$, is here introduced, which means that for each condition of P and θ_0 there will now be a family of swing curves corresponding to different values of ϕ. Again, any such system of curves can readily be plotted by experiment with the help of this mechanical analogue.

DETERMINATION OF CRITICAL SWITCHING TIMES

An important part of many transient stability studies is the predetermination of critical switching times, that is to say, the calculation of the maximum safe time for which a prescribed fault may remain on a system before it is isolated by switching, yet maintaining stable running, or, in the case of transitory faults, the maximum period for which a circuit may be interrupted before restoring conditions by reclosing the switches. Such information is essential for assessing the required characteristics of the switchgear and relays concerned. A valuable aid in this work is the equal-area stability criterion,[2,3,5,9] which is a simple method of finding the critical switching angle. Considering Fig. 4, the three graphs represent the power/angle relationships, before, after, and during a fault on a particular reactive network. The fault occurs when a power P_0 is being transmitted, at a phase angle θ_0, the machine accelerates, and θ increases. It is clear that if no steps are taken to prevent it, synchronism will be lost, but if the faulty section is isolated when $\theta = \theta_1$, it can be readily shown that the system will remain stable provided area 2 is equal to or greater than area 1. The critical condition occurs when these areas are equal; the geometry of the figure shows this to be the case when

$$\theta_1 = \cos^{-1}\left\{\frac{\sin\theta_2(\theta_2 - \theta_0) - r_1\cos\theta_0 + r_2\cos\theta_2}{r_2 - r_1}\right\} \tag{15}$$

where

$$r_2 = \frac{\text{interconnector reactance before fault}}{\text{interconnector reactance after fault}}$$

$$r_1 = \frac{\text{interconnector reactance before fault}}{\text{interconnector reactance after fault}}$$

Having established this critical switching angle it is usual to apply one of the step-by-step or graphical methods already referred to, in order to find the corresponding critical switching time, but the labor involved in this procedure can be saved by setting up the problem on a flywheel model. With the driving and riding weights arranged in accordance with curves a and c respectively, and θ at θ_0, i.e. with the model in the immediate postfault condition, it is freed from constraint and allowed to swing. The time it takes to reach the critical angle defined by equation 15 is the critical clearing time sought.

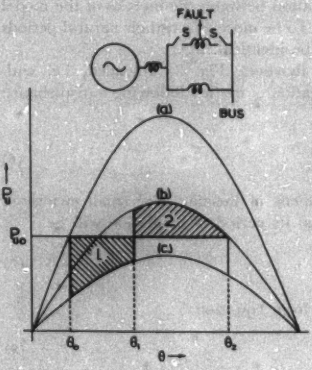

Fig. 4. Power/angle curve for a faulted system

(*a*) *Prefault curve, switches S closed*
(*b*) *Postclearance curve, switches S open*
(*c*) *Fault curve, switches S closed and fault on*

If the postswitching period is of interest, the act of isolation can be simulated. In Fig. 4 the operation of switching involves the sudden transition from curve c to curve b, which, for the model, means a sudden increase in the riding weight. This is quite easily brought about by arranging for a pin on the flywheel to pick up a weight at the appropriate juncture in the course of its travel (see Fig. 5).

Byrd and Pritchard[10] have published a set of master curves from which the critical switching time corresponding to any specified value of θ_0, r_1 and r_2 can be established; they again used the concept of a modified time, so that the curves are quite general in their application. These, and any similar curves, such as a family from which

critical reclosing times might be found, could be constructed with small labor with the aid of a flywheel model.

THE 2-MACHINE PROBLEM

THE treatment given in the preceding paragraphs has been confined to the simple problem of a machine, impedance, and an infinite bus, but in so far as a system having two finite machines with an impedance link can be reduced to such a simple system, all 2-machine problems

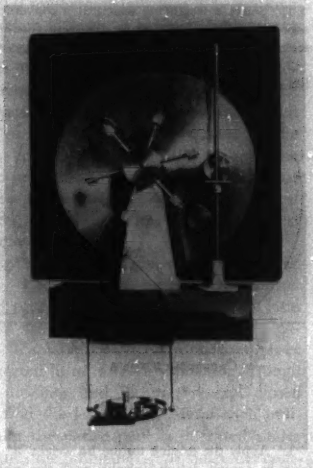

Fig. 5. The flywheel analogue

are soluble by the analogue. The method of resolving the 2-machine problem to one finite machine and an infinite bus will be found in references 3, 4, and 5.

This is the limit of the flywheel model, and it seems safe to assert that any analogue depending upon gravity for synchronizing forces cannot be extended beyond two machines.

DAMPING, GOVERNORS, AND REGULATORS

THE damping forces which may act upon a machine rotor during transient phase swing can be conveniently classified according to their origin:

1. Asynchronous damping forces in the synchronous machine itself.[11]
2. Changes of input torque due to the operation of the governor on the prime mover.
3. System damping introduced by changes in the electric load due to change of system voltage consequent upon the disturbance; this is, closely related to the voltage regulator characteristic.[12]

In most transient stability studies damping is neglected because either it is insignificant, or sufficient information is not available to make an accurate assessment of its magnitude. Alternatively the system engineer salves his conscience by pointing out that to neglect damping is to take a pessimistic view of the system's performance. When damping is considered it introduces a modest complication to an already rather protracted calculation. In contrast most of the damping forces can be treated on the flywheel model with little difficulty.

Concerning point 1, energy is here transferred from stator to rotor or conversely by induction motor or induction generator action; it is most marked in machines fitted with amortisseur windings. For the small changes of speed involved the amount of energy will be proportional to the slip, i.e., it may be taken account of in the swing equation by a term $C\frac{d\theta}{dt}$ where C is a constant.[11] In the model it can be provided by eddy currents in the disk of the flywheel (or an auxiliary disk on the shaft if more convenient) induced by an electromagnet near the rim.

Prime mover input on the model is characterized by the weight W, but the torque which W provides might well be obtained electromagnetically. This would lead to a flexible control of input torque, a control which could follow any predetermined pattern that governor characteristics might dictate.

The simulation of system damping is perhaps more difficult, but assuming adequate information is available it seems not inconceivable that the position of w might be adjusted as the flywheel swings, so that its torque might conform with any desired power demand resulting from action mentioned under point 3.

EFFECTS OF SALIENCY

IT is well known that the torque/angle (or power/angle) curve of a salient-pole machine is not a sinusoid even when joined to a bus by pure reactance. The expression for torque (or power) contains a biharmonic term arising from variations in the air-gap reluctance. The output power of a salient pole alternator is given by[2,3]

$$Pu = \frac{EV}{x_d}\sin\theta' + \frac{V^2(x_d - x_q)}{2x_d x_q}\sin 2\theta' \qquad (16)$$

where

E = generated emf of the alternator
V = terminal voltage of the alternator
θ' = phase angle between E and V
x_d and x_q = direct and quadrature axis reactances of the machine

The second term may contribute up to 25 per cent of the power output. Dahl (reference 3, p. 385) has developed a corresponding expression which takes account of external reactance; it again contains a term in $2\theta'$. There would seem to be no elegant method of simulating this term on the flywheel model, though the obvious method of driving an out-of-balance weight through a 2-to-1 reduction gear would probably be quite satisfactory.

THE FLYWHEEL MODEL EQUIPMENT

The model is shown in Fig. 5. It is essentially a carefully balanced flywheel (final balancing is achieved by adjusting the capstan weights) mounted with its axle horizontal, between a pair of pedestal bearings. Because bearing friction can introduce sufficient damping as to

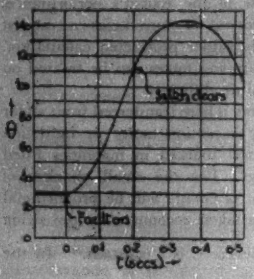

Fig. 6. Replica of a swing curve drawn by the model

vitiate experimental results completely, the device is fitted with special gyroscope bearings and friction is thereby reduced to a torque of less than 5 gm-cm. The vital importance of keeping friction at a very low level cannot be overstressed. The moment of inertia of the flywheel is approximately 0.16 kgm² and the riding weights used are in the range 100–300 gm; they operate at a radius of 10 cm.

The progress of the flywheel during the course of a swing is recorded by a very light stilus on an electrosensitive paper. This recorder, developed by C. B. Cooper of the University of Leeds, plots a swing curve directly on cartesian co-ordinates: Fig. 6 is an example. Thus in many instances the problem is completely solved and the answer presented in a convenient form in a matter of seconds.

Appendix

RECEIVING END CONDITIONS

For a line without admittance, the power received by the bus bar is given by

$$P_r = \frac{E_1}{Z}[E_2 \cos(\phi - \theta) - E_1 \cos\phi] \qquad (17)$$

This equation, like equation 2, can be represented by a circle diagram. The two diagrams are frequently combined, as has been done in Fig. 7. The flywheel model can most adequately illustrate this combined diagram if it be arranged that the model drive a second pointer (engraved on a perspex disk, for example), representing the bus-bar vector.

THE GENERAL CASE, AN INTERCONNECTOR WITH ADMITTANCE

If the source and bus bar are joined by a general network so that the output of the machine is regulated by equation 1, the analogue is basically unchanged, and the weights have their original significance though they now represent more complex quantities. From equation 1 it is apparent that P_R is again made up of two components, one fixed and one variable, which will once more be accommodated by weights W' and w. In these circumstances $W'a = \frac{DE_1}{B}\cos(\beta - \theta)$, whereas $wb = \frac{E_1E_2}{B}$.

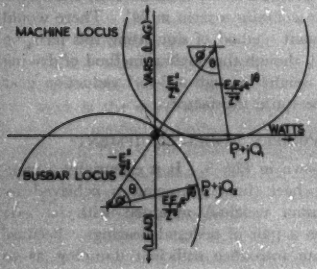

Fig. 7. Combined circle diagram for machine and bus bar

There is one noteworthy change. It will be observed from Fig. 8, which is the circle diagram relevant to these conditions, that θ is no longer measured from the same datum as formerly.

The procedure for setting up the analogue to make a study of a specific general circuit would be as follows:

1. Select a weight w, which at a convenient radius will give an acceptable natural period for transient studies, and so set the time scale.

2. Add weight W' sufficient to displace the radius in which w lies $(\pi/2 - \beta)$ from the vertical.

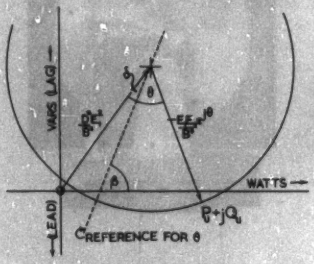

Fig. 8. Circle diagram for machine connected to an infinite bus bar through a general network

3. Apply the driving torque by weight W, so that θ as measured from its correct datum complies with the initial phase angle of the problem.

A fault on the circuit may well now involve a change in W' as well as w.

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Tensorial Analysis of Transmission Systems—IV

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THIS ARTICLE undertakes something unique in the application of mathematical methods to the solution of physical problems. It has long been universally believed by engineers and mathematicians that if a very long and complicated problem is given, it is not possible to cut the problem into several shorter and simpler parts, solve each part separately, then interconnect the partial solutions, in order to arrive thereby at the exact solution of the original complex system itself. People always argued that it is necessary to have available the answer to the entire problem first, before an answer valid to only one portion of it may be arrived at. It was argued that one must know the effects of forces impressed at the farthest corner of an assembly, before the behavior of the nearest group could be predicted.

This article accomplishes just that feat of solving a large problem piecemeal. The example used as illustration of a universally valid procedure is the individual and total i^2r loss calculation of the transmission system of an extensive power pool. The latter consists of numerous power companies interconnected in an arbitrary manner through a large number of tie-lines and forming several closed loops. In order to find the loss coefficients of each individual company when the entire pool is operated under any scheduled program, the following steps must be complied with:

1. The pool is subdivided into its operating companies.
2. The loss coefficients of each individual company are determined, as if the other companies were nonexistent, by the method of part I of this serial.[1] (This step involves most of the computational work.)
3. The companies are interconnected.
4. The loss coefficients are also interconnected in an analogous manner.

The final interconnected answer represents the loss coefficients of the entire pool, as well as the loss coefficients of each individual company, to be used in the presence of all the other companies operating, also exporting and importing power to each other, in an arbitrary manner. A numerical example of a 3-company pool forming one closed loop is worked out in the companion paper.[2]

The procedure is based upon the extremely simple and innocent looking, but fundamentally very subtle and powerful concept of "primitive" system, developed by the author during the last quarter century and elaborated in numerous books and articles. This same method of tearing apart large systems into smaller ones, then solving and interconnecting the particle solutions, is applicable to all types of physical systems running the whole gamut of classical to relativistic and quantum physics in all possible combinations. Physical systems describable by partial or ordinary differential equations, by integral or algebraic equations, be they linear or—with certain precautions—nonlinear systems, are all amenable to this fractional method of solution. Problems of the Calculus of Variations with a large number of variables are especially suited for this type of analysis and solution. The reader interested in more general applications and theories should consult reference 3, in which a boundary value problem of Poisson's equation is worked out as an example.

Besides permitting the analysis and solution of very large-problems that otherwise would be impractical to undertake, the method of tearing proves a very effective labor. saving device in the solution of smaller problems also Let such an elementary problem as the inversion of a matrix (describing the linear algebraic equations of a physical system) be considered either on a slide-rule or on a digital computer. Tearing the physical system into n parts reduces the necessary time of inversion on the computer to a fraction of about $2/n$.[3] With $n=10$, the fraction is 1/50 and with $n=100$, the fraction decreases to 1/5,000. A road is thereby opened up to attack and solve in a reasonable time problems with tens of thousands and perhaps with hundreds of thousands of variables by utilizing only already existing electronic digital computers.

Surprisingly enough, a solid background and ability in the tensorial analysis and solution of very large electric networks, such as electric power engineers are accustomed to deal with, is a well-nigh indispensable prerequisite to perform efficiently the afore-indicated solutions of hitherto unsolvable problems in all branches of the physical sciences. For further details the reader is again referred to reference 3.

As the tempo of our industrial civilization accelerates, the subject of tearing apart very large physical systems and solving them piece-wise cannot help but acquire more practitioners and an increasingly greater variety of basic concepts and methodologies. The author would like to denote this slowly emerging new science with the Greek name "*diakoptics*". It comes from the word "kopto" meaning "to break", or "to tear apart". The prefix "dia" merely reinforces the word to follow, as the English "very."*

Digest of paper 53-253, "Tensorial Analysis of Integrated Transmission Systems—IV. The Interconnection of Transmission Systems," recommended by the AIEE Committee on System Engineering and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer General Meeting, Atlantic City, N. J., June 15-19, 1953. Published in AIEE *Power Apparatus and Systems*, August 1953, pp. 827–39.
Gabriel Kron is with the General Electric Company, Schenectady, N. Y.

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* The name was suggested by Professor Philip Stanley, of the department of philosophy at Union College, Schenectady, N. Y.

A Simplified Standard Cell Comparator

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FELLOW AIEE

THE USE OF the saturated or "Normal" form of Weston standard cell appears to be growing. Today numerous industries and college laboratories are maintaining groups of saturated cells whereas a decade ago relatively few banks existed outside the National Bureau of Standards.

Such cells, while maintaining their voltage well against time in years, must be maintained in a temperature-controlled chamber since the change in voltage with temperature is about 60 microvolts per degree C. For standardizing the unsaturated cells in terms of the values of a "Normal" saturated bank, a simple comparator of some sort is desirable.

In checking a working standard cell against a reference standard, the two cells are connected in opposition in series with a galvanometer and an auxiliary source of a few microvolts. A comparator is simply a means of adjusting the auxiliary potential, indicating its value in microvolts in some manner and possibly with an arrangement whereby it can be added, simply, accurately, and with proper sign, to the value of the reference cell.

The comparator designed by H. B. Brooks, and reported in Research Paper number *586* of the Bureau of Standards, August 1933, is a highly developed form in which readings can be made to 0.1 microvolt. A comparator of simpler scope having a sensitivity level of 1 microvolt with an overall limit of error of 5 microvolts has been designed for industrial use. It is shown in Fig. 1 assembled with the necessary auxiliary items including 2 milliammeters, an auxiliary standard cell, three dry cells, and the main galvanometer of high sensitivity; the interconnecting wiring has been omitted for clarity. The schematic diagram (Fig. 2) includes all of the auxiliary items; open circles represent binding posts.

Fig. 1. Comparator with associated milliammeters, dry cells, main galvanometer, and auxiliary standard cell

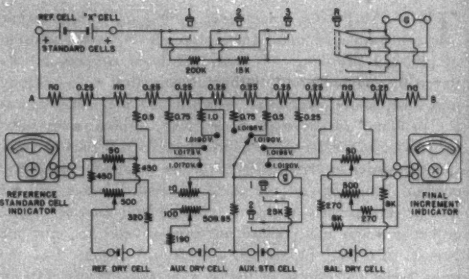

Fig. 2. Schematic diagram of comparator with all auxiliary items

The circuit of the reference cell and the cell under test, *X*, is closed to the high-sensitivity galvanometer *G* through the resistance from *A* to *B* which actually takes the form of a few feet of *#24* gauge manganin wire wound on a skeleton bakelite form to give 1/4 ohm per turn.

The left-hand Model *1* instrument (see Fig. 1) has a range of 1-0-1 milliampere (ma); the instrument scale is marked, however, 1.017750 to 1.018250 volts, with 1.018000 volts at the electrical zero point. The current is adjusted so that the instrument indicates the acutal reference cell potential; the drop of this measured current through the 0.25-ohm resistor adjusts the net voltage to 1.018000 volts.

Current through the center 0.25-ohm resistors is maintained at exactly 2 ma by balancing against an auxiliary standard cell as in the Brooks design. Selection of the switch position adds or subtracts 500-microvolt steps to the reference voltage. Final adjustment to balance by the network at the right produces the final microvolt value as measured in the right-hand instrument. The indicated value then is added to the value marked on the switch point in use.

A brief analysis of the circuit will show that only the marked resistors in the circuit from *A* to *B*, and the 509.85-ohm resistor need be adjusted accurately; they were held to 0.1 per cent. All of the other resistors serve adequately if within a few per cent of the marked value including the control rheostats.

In presenting this particular form of comparator, full credit must be given to Dr. Brooks for his original paper from which this design is abstracted.

Digest of paper 54-208, "A Simplified Standard Cell Comparator," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Published in AIEE *Communication and Electronics*, September 1954, pp. 413–6.

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A Symmetrical Component Synthesizer and Analyzer

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The basic formulas of the method of symmetrical components may be verified and the elliptical pattern produced by unbalanced currents can be analyzed to determine directly from the dimensions of the ellipse the magnitudes of the positive and negative sequence components by means of the polyphase oscilloscope developed at the State University of Iowa.

THE METHOD of symmetrical components used in analyzing unbalanced conditions in power networks and rotating machines has been known for more than 30 years. However, up to the present time there has not been any convenient procedure for experimentally verifying the basic formulas employed. By the use of the polyphase oscilloscope[1-4] developed at the State University of Iowa these basic formulas have been verified for 3-phase, 3-wire, Y-connected, unbalanced circuits. In addition a simple method for experimentally determining the magnitudes of the positive and negative sequence components was discovered.

SYMMETRICAL COMPONENTS

THE method of symmetrical components is based on the principle that any unbalanced 3-phase system of vectors can be resolved into three balanced systems of vectors, namely: (1) a balanced system of 3-phase vectors called the positive sequence system, having the same phase sequence as the original unbalanced system of vectors; (2) a balanced system of 3-phase vectors called the negative sequence system, having the opposite phase sequence from the original unbalanced system of vectors; and (3) a system of 3 single-phase vectors equal in magnitude but having the same time-phase position with respect to any given reference axis. The last system is called the zero-sequence system. Since only 3-phase, 3-wire, Y-connected circuits were studied, zero-sequence components were not present. This restriction was made necessary as the polyphase oscilloscope is not capable of indicating the presence of this component. The zero sequence current can, however, be read directly with an ammeter placed in the fourth or neutral conductor.

If the original unbalanced vector quantities are known, they can be resolved into their equivalent positive and negative components by means of the well-known basic formulas which follow. If, for example

$$I_A = 7.04 \angle 0°$$
$$I_B = 5.82 \angle 148°$$
$$I_C = 3.74 \angle -124°$$

are the original unbalanced vectors, then the positive-sequence component may be calculated, thus

$$I_{a1} = 1/3(I_A + I_B \angle -120° + I_C \angle +120°)$$
$$= 5.36 \angle 8.8°$$

Likewise the negative-sequence components may be calculated, thus

$$I_{a2} = 1/3\,(I_A + I_B \angle +120° + I_C \angle -120°)$$
$$= 1.92 \angle -25.4°$$

It is these basic formulas that were experimentally verified by means of the polyphase oscilloscope when used as a synthesizer. The verification was accomplished by comparing the screen pattern produced by the original unbalanced currents flowing in a 3-phase deflection system with the resulting screen pattern produced by the use of

Fig. 1. 3-Phase oscilloscope showing front 3-phase magnetic deflection system, lateral adjustment, axial adjustment, and calibrated scale

the calculated values of positive and negative-sequence currents flowing in two separate 3-phase deflection systems respectively.

3-PHASE DEFLECTION SYSTEMS

THE 3-phase deflection systems employed in this study are of the magnetic type placed externally around the neck of a cathode-ray tube as shown in Fig. 1. Each

A special article recommended for publication by the AIEE Committee on Instruments and Measurements.

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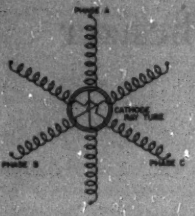


Fig. 2. Space location of the 3-phase magnetic deflection coils around the neck of the cathode-ray tube

magnetic yoke is made up of six coils spaced 60° apart. The coils diametrically opposite each other constitute one phase and are connected in series as shown in Fig. 2. Three coil combinations displaced 120° from each other in space are thus formed. Each coil on the yoke nearest the screen is composed of 68 turns of no. 16 American Wire Gauge enamel-insulated copper wire, while each coil on the yoke nearest the electron gun is wound with 49 turns of the same wire. The difference in coil turns on the two yokes is necessary in order to give both yokes the same deflection sensitivity. Precise equality in sensitivity is obtained by means of a lateral adjustment of one yoke with respect to the other. Provision is also made for rotating one yoke through an angle of 60° with respect to the other yoke. Fig. 1 shows the adjustment slot for moving the front yoke forward or backward, and the sector slot for rotating the rear yoke axially. The calibrated scale is also visible in the figure. All of the coil cores are made of wood, and the cylindrical coil and yoke supports are made of brass. A front view of the two magnetic deflection yokes with cathode-ray tube removed is shown in Fig. 3.

SCREEN PATTERNS

It is well known that an alternating current flowing in a single deflection coil will cause the electron beam to oscillate to and fro producing a straight line on the screen. Also, it is well known that balanced 3-phase sinusoidal alternating currents flowing in a 3-phase deflection system will produce a circular pattern on the screen as shown in Fig. 4. This is similar to the constant magnitude and constant angular velocity flux field produced in the stator of a 3-phase induction motor. If, however, the 3-phase currents are not balanced then the screen pattern changes from a circle to an ellipse as shown in Fig. 5. A diagrammatic sketch of the apparatus and connections employed to produce these patterns is shown in Fig. 6. The reproduction of an identical ellipse by using the corresponding calculated balanced positive-sequence currents in one deflection system and the corresponding calculated balanced negative-sequence currents in the other deflection system constitutes the desired experimental verification. In other words, the original ellipse produced with the unbalanced currents will be synthesized and reproduced by combining the effects of the corresponding positive- and negative-sequence component currents.

Fig. 3. Front view of the two deflection yokes of the 3-phase oscilloscope with cathode-ray tube removed

SYNTHESIZING AN ELLIPSE

The locus of the resultant of two oppositely rotating vectors having the same angular velocity, describes an ellipse. For the special case where the two oppositely revolving vectors are equal in magnitude, the ellipse formed is completely collapsed, that is, has a minor axis equal to zero. Thus in Fig. 7 are shown two circular patterns produced by two equal but oppositely revolving magnetic vectors and the resulting ellipse in the form of a straight line. The formation of this straight line is illustrated in Fig. 8 where H_{11} and H_{21} are the equal but oppositely revolving vectors both having the same angular velocity ω. The resultant H_{01} varies in magnitude from zero to a maximum of H_{00} produced when the vectors are in phase as they cross each other, and back to zero when the vectors are 180° apart or diametrically opposite each other. Beyond 180° the vectors approach each other again and produce a resultant in the opposite direction. It can thus be said that two equal vectors rotating oppositely at constant angular velocity combine to produce a resultant which alternates in direction and varies from zero to maximum and back to zero in both directions. The trace of this resultant on the oscillographic screen is thus similar to that which would be produced by a single-phase alternating current flowing in a single deflection coil.

When the two oppositely revolving vectors are unequal in magnitude the screen patterns appear as in Fig. 9. The two unequal circles are the traces of the oppositely revolving vectors and the ellipse is the pattern formed by the resultant of the two vectors. What was a straight line in Fig. 7 has now opened up, so to speak, into the customary form of ellipse. In a manner similar to that employed in Fig. 8, the vector addition is carried out in Fig. 10, where H_{11} and H_{21} are again the oppositely revolving but unequal vectors and H_{01} is the resultant for the instant illustrated. H_{01} is therefore one point on the ellipse. In the cathode-ray oscillograph, however, the beam is deflected at right angles to the magnetic field and therefore the ellipse which appears on the screen is actually rotated 90° from its true position. Likewise in Figs. 7 and 8 the straight line which appeared on the screen is also at right angles to the actual magnetic resultant.

Fig. 4 (far left). Circle produced by balanced 3-phase currents flowing in a 3-phase deflection system. Fig. 5 (left). Ellipse produced by unbalanced 3-phase currents flowing in a 3-phase deflection system. Fig. 7 (right). Circular patterns produced by two equal but oppositely revolving vectors and the resultant straight line, being an ellipse having a minor axis equal to zero. Fig. 9 (far right). Circular patterns produced by two unequal but oppositely revolving vectors and the resultant in the form of an ellipse

EXAMPLES

THREE cases of current unbalance will be illustrated. The reader is aware that in the case of balanced currents the negative sequence component is absent leaving only the positive sequence component. And as was already pointed out, balanced 3-phase currents flowing in a 3-phase deflection system produce a rotating flux field of constant magnitude as in a polyphase induction motor stator. Such a flux field will drive the electron beam around in a circle of constant radius as shown in Fig. 4.

Case I. As soon as the circuit becomes unbalanced, however, a negative sequence component appears as in Case I for which the data are as follows:

$I_A = 7.04 \angle 0°$ $\quad I_{a1} = 5.36 \angle 8.8°$
$I_B = 5.82 \angle 148°$ $\quad I_{a2} = 1.92 \angle -25.4°$
$I_C = 3.74 \angle -124°$

The unbalanced currents flowing in the deflection yoke produce one of the ellipses shown in Fig. 11 and the two component currents flowing separately in two deflection yokes respectively produce the pattern previously illustrated in Fig. 9. When this pattern is superimposed as in Fig. 11 the synthesized ellipse coincides with the ellipse produced by the original unbalanced currents as shown.

Case II. A condition of greater unbalance is illustrated in Case II for which the data are as follows:

$I_A = 6.32 \angle 0°$ $\quad I_{a1} = 4.12 \angle 25.2°$
$I_B = 6.32 \angle 171°$ $\quad I_{a2} = 3.20 \angle -3.42°$
$I_C = 0.946 \angle -97°$

Again Fig. 12 shows the separate component patterns as well as the resulting ellipse. In Fig. 13 this ellipse is again superimposed upon the ellipse formed by the original unbalanced currents. A high degree of coincidence is evident.

Case III. The condition of greatest unbalance exists when one of the line currents is zero making the remaining line currents equal and opposite in phase. The data for this Case III are as follows:

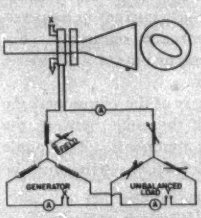
$I_A = 6.46 \angle 0°$ $\quad I_{a1} = 3.74 \angle 30°$
$I_B = 6.46 \angle 180°$ $\quad I_{a2} = 3.74 \angle -30°$
$I_C = 0$

In this extreme unbalance the positive and negative sequence components are equal and when flowing in separate yokes produce circles of equal diameter. And as was shown in Fig. 7 two equal and oppositely rotating vectors produce a resulting straight line. In Fig. 14 this straight line is superimposed on the straight line formed by an alternating current flowing through coils *a* and *b* in series.

In the foregoing examples both sets of sequence currents could have been produced by the same generator. However, the use of separate generators as shown in Fig. 15 with individual voltage control made possible finer adjustment of the balanced currents than would have been possible by changing the resistive loads only.

SETTING PHASE ANGLES

THE desired phase-angle settings for the positive and negative sequence components could be obtained by the use of appropriate combinations of resistance and inductance and resistance and capacitance in the loads. A simplification, however, is possible by employing pure resistive loads for both positive- and negative-sequence loads and providing the required total phase angle displacement by rotating one of the deflection yokes. It can be shown that a space angle shift is equivalent to the



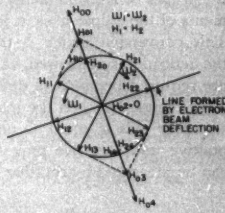


Fig. 6 (left). Wiring diagram for obtaining elliptical patterns on cathode-ray tube from unbalanced currents. Fig. 8 (right). Vector diagram showing how two superimposed equal and oppositely rotating magnetic fields form a pulsating field along an axis in the plane of rotation

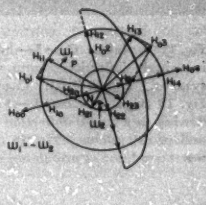


Fig. 10. Vector diagram showing how two superimposed unequal and oppositely rotating magnetic fields form an ellipse in the plane of rotation

corresponding time angle difference. It is for this reason that one of the deflection yokes is so mounted that it can be rotated 60°, the maximum amount of shift required. The worst condition of unbalance possible is that illustrated in Case III where the two time phase angles are $+30°$ and $-30°$, making a total time angle difference of 60°. Therefore a 60° shift of one of the yokes is all that is needed.

It should be noted that the angle the major axis makes with the reference axis will only be one half of the total angular difference.

ANALYZING AN ELLIPSE

An analysis of the ellipse for the positive- and negative-sequence components can be made by measuring the length of the major and minor axes of the ellipse. It has been shown that the ellipse is produced by two oppositely rotating vectors having the same angular velocity. Twice during every revolution of these vectors they are in phase and twice during every revolution they are in phase opposition. If the larger of these vectors is designated P and the smaller of these vectors N, then the magnitude of the major axis of the ellipse will be equal to

$$2(P+N) = \text{length of major axis}$$

Correspondingly the magnitude of the minor axis of the ellipse will be equal to

$$2(P-N) = \text{length of minor axis}$$

These dimensions are illustrated in Fig. 16. A solution of these simultaneous equations yields

$$P = (\text{major} + \text{minor})/4$$
$$N = (\text{major} - \text{minor})/4$$

The magnitudes of P and N will be the magnitudes of the positive-sequence and negative-sequence components when the proper conversion factor is used to convert the measurements of the ellipse axes in inches into current in amperes. This conversion factor is the deflection sensitivity. For the deflection system used, balanced currents of 5.0 amperes are required per inch of deflection.

The angle between the major axis of the ellipse and the reference axis is equal to one-half the angle between the positive and negative sequence components. This angle can be measured by rotating the deflection system until the major axis of the ellipse coincides with the reference axis. The angular rotation of the deflection system is read on the calibrated scale shown in Fig. 1.

This method of analysis may be illustrated by referring to Case I. A measurement of the axes of the ellipse shown in Fig. 11 yields: major axis $=2.93$ inches; minor axis $=1.36$ inches. Applying the formulas developed in the foregoing

$$P = \frac{2.93+1.36}{4} = 1.07 \text{ inches}$$

$$N = \frac{2.93-1.36}{4} = 0.39 \text{ inch}$$

Converting these values to currents by the use of the deflection sensitivity constant gives

$$P = 1.07 \times 5.0 = 5.35 \text{ amperes}$$
$$N = 0.39 \times 5.0 = 1.95 \text{ amperes}$$

These values agree very closely with the values of positive and negative sequence components computed for Case I of $P=5.36$ amperes, and $N=1.92$ amperes. The deflection system was rotated through an angle of 17.5° to return the major axis of the ellipse to the reference axis. This angle is approximately one half of the angle between I_{a1} and I_{a2} for Case I where the total angle is $8.8°+25.4°=34.2°$.

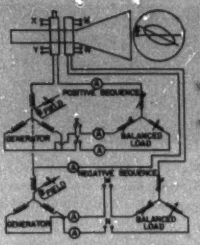


Fig. 15. Wiring diagram for obtaining elliptical patterns on cathode-ray tube from balanced currents flowing in two separate systems

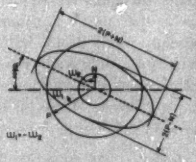


Fig. 16. Sketch illustrating method of determining positive and negative sequence components from measurement of major and minor axes of ellipse

CONCLUSIONS

Visible evidence of unbalance occurring in a 3-phase, 3-wire, Y-connected circuit may be presented by the appearance of an ellipse on the screen of an oscilloscope using a 3-phase deflection system. Such a 3-phase oscilloscope may be used in two ways:

1. To verify the formulas of the method of symmetrical

Fig. 11 (far left). Case I—showing two ellipses superimposed upon one another. One ellipse is formed by unbalanced currents flowing in a single deflection system, and the other by the positive and negative sequence component currents flowing in two separate deflection systems. Fig. 12 (left). Case II—screen pattern of synthesized ellipse as well as patterns of positive and negative sequence components. Fig. 13 (right). Case II—showing two ellipses superimposed upon one another. One ellipse is produced by unbalanced currents flowing in a single deflection system and the other by the positive and negative sequence component currents flowing in two separate deflection systems. Fig. 14 (far right). Case III—showing two ellipses superimposed upon one another. One ellipse is formed by worst condition of unbalance possible and the other by equivalent positive and negative sequence component currents flowing in separate deflection systems

components by synthesizing an ellipse produced by unbalanced currents by using two 3-phase deflection systems carrying balanced currents equal to the equivalent positive and negative sequence components of the unbalanced currents.

2. To analyze the elliptical pattern produced by unbalanced currents in order to determine directly from the dimensions of the ellipse the magnitudes of the positive and negative sequence components.

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High-Coercive-Force Permanent-Magnet Materials and Their Application

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A GREAT DEAL has been written about the desirability of high maximum energy product (BH_{max}) in permanent-magnet materials, and many authors have discussed the design of magnets to take full advantage of this quantity under various magnetic circuit conditions.[1] No attempt will be made here to review or add to this extensive literature, but rather this article will concern itself with those permanent-magnet materials characterized by high intrinsic coercive force (H_{ci}), and will review some design opportunities and problems involved in their applications. Information is included on the ellipsoid approximation method for estimating the flux output of short magnets, where the usual magnetic circuit calculations are inapplicable, since this information is particularly useful in the application of high-coercive-force materials.

The characteristics of high-coercive-force permanent-magnet alloys are reviewed and some of the opportunities and problems involved in their application are discussed.

Table I and Figs. 1, 2, and 3 summarize the magnetic properties of ten permanent-magnet materials with intrinsic coercive forces greater than 750 oersteds. The design characteristics of each will be briefly reviewed.

Silmanal, one of the Heusler alloys, has the composition 86.75 per cent silver, 8.8 per cent manganese, and 4.45 per cent aluminum. Its nondirectional magnetic properties are developed by 75 per cent cold reduction, followed by a precipitation treatment and aging at 250 C. The Curie temperature is 360 C. Silmanal is ductile and machinable, with a density of 9.0 grams per cubic centimeter. Its low-residual induction limits application to special cases where maximum resistance to demagnetization is essential, as in polarized relays, voltage regulators, and gaussmeters.

Cobalt-platinum is an order hardening alloy of 77 per cent platinum and 23 per cent cobalt (CoPt), magnetically nondirectional, with a Curie temperature of 500 C. It is ductile and machinable in the quenched, disordered condition before aging. It has the high physical density of 15.5 grams per cubic centimeter. Jellinghaus[2] reported in 1936 a maximum energy product of 3.8 million gauss-oersteds, a value which has recently been doubled as a result of work by Geisler and Martin.[3,4] Unfortunately its extremely high cost limits its application to small magnets for special applications.

There is a similar alloy of 78 per cent platinum and 22 per cent iron, FePt, with a maximum energy product of about 3 million gauss-oersteds.[1] An intrinsic coercive force of 20,000 oersteds has been reported by Weil[5] for this alloy when prepared by the thermal decomposition of ferrous platinocyanide.

Manganese-bismuth is a particularly interesting example of a single-domain fine-particle magnet, composed of the intermetallic compound MnBi, 79 per cent bismuth, 21 per cent manganese. The Curie temperature is 350 C. Guillaud* discovered that its hexagonal crystal structure has the very high crystal anisotropy energy value of 11.6 million ergs per cubic centimeter (compared to 0.5 million

Full text of a conference paper presented at the AIEE Winter General Meeting, New York, N. Y., January 18–22, 1954, and recommended for publication by the AIEE Committee on Basic Sciences.

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* Ferromagnetic Binary Alloys of Manganese (thesis), **C. Guillaud.** University of Strasbourg, France, 1943.

Table I. Magnetic Properties of High-Coercive-Force Permanent-Magnet Materials

	Material	H_{ci}	H_c	B_r	$(BH)_m \times 10^{-6}$
1.	Silmanal	6,000	550	550	0.076
2.	Cobalt platinum	5,000	4,000	5,700	7.5
3.	Manganese bismuth		3,400	4,300	4.5
4.	Directional barium-iron oxide		2,000	3,500	3.0
5.	Nondirectional barium-iron oxide	2,900	1,500	2,000	0.8
6.	Vectolite	1,100	1,000	1,600	0.6
7.	Cunife VII	1,100	1,000	2,800	1.2
8.	Alnico VII	1,050	1,000	7,200	2.75
9.	Cunico IV	900	800	2,900	0.8
10.	Alnico VI	775	750	10,000	3.5

H_c, H_{ci} oersteds; B_r gauss
$(BH)_m$ gauss oersted $\times 10^{-6}$

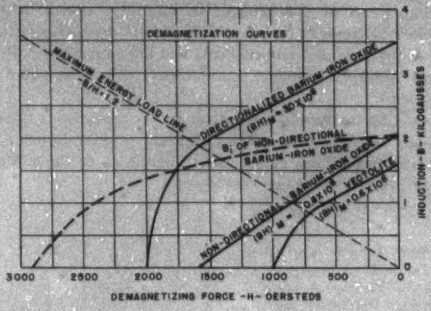

DEMAGNETIZATION CURVES
MAXIMUM ENERGY LOAD LINE -B/H=1.8
1-DIRECTIONALIZED BARIUM-IRON OXIDE (BH)m=3.0 X10⁶
Br OF NON-DIRECTIONAL BARIUM-IRON OXIDE
NON-DIRECTIONAL BARIUM-IRON OXIDE (BH)m=0.8X10⁶
VECTOLITE (BH)m=0.6X10⁶
INDUCTION - B - KILOGAUSSES
DEMAGNETIZING FORCE -H- OERSTEDS

Fig. 2. Demagnetizing curves of barium-iron oxide and Vectolite

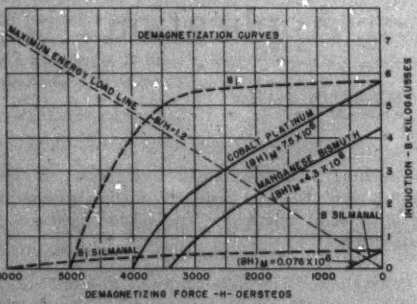


Fig. 1. Demagnetizing curves of cobalt-platinum, manganese-bismuth, Silmanal

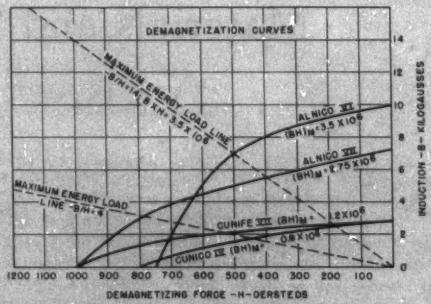

DEMAGNETIZATION CURVES
MAXIMUM ENERGY LOAD LINE -B/H=1.4 & X10⁶=3.5
ALNICO VI (BH)m=3.5 X10⁶
ALNICO VII (BH)m=2.75 X10⁶
MAXIMUM ENERGY LOAD LINE -B/H=4
CUNIFE VII (BH)m=1.2X10⁶
CUNICO IV (BH)m=0.8 X10⁶
INDUCTION - B - KILOGAUSSES
DEMAGNETIZING FORCE -H- OERSTEDS

Fig. 3. Demagnetizing curves of Alnico VII, Cunife VII, Cunico IV, Alnico VI

for iron), and observed that fine particles crushed to about 3 microns in particle size and aligned by a magnetic field, showed an intrinsic coercive force of 12,000 oersteds. A value of 14,500 oersteds has been observed by the authors in unpublished work. Unfortunately the high crystal anisotropy of this material drops rapidly at temperatures below room temperature, with a consequent inherent 50 per cent loss of coercive force at −65 C.

Recent work by Adams[6–7] has resulted in the permanent-magnet properties shown. The process consists of hot-pressing finely powdered MnBi with some excess molten bismuth in a strong magnetic field. This material, named "Bismanol," has a physical density of 8.1 grams per cubic centimeter. Applications await further development work, and may be hampered by the large temperature coefficient of coercivity.

Barium-iron oxide is a hexagonal oxide compound of the formula $BaO \cdot 6Fe_2O_3$, which apparently derives its high coercive force from single-domain particles of high crystal anisotropy, Rathenau[8–11] and his co-workers reporting an anisotropy constant of 3 million ergs per cubic centimeter for the material. The material, called "Ferroxdure" in Europe, is now being introduced into America under various trade names. It has a physical density of 4.8 grams per cubic centimeter, a Curie temperature of 450 C, and a high degree of temperature stability. With the hardness and brittleness of a ceramic, it is usually pressed and sintered to shape, although grinding is possible.

As originally developed, the material was nondirectional, but Rathenau has more recently described an oriented version,[12] which is not at present commercially available; the properties of both types are presented. It is still too early to describe the American applications of this new high-coercive low-cost permanent-magnet material.

Vectolite is a cobalt-iron oxide, 26 per cent Co_2O_3, 30 per cent Fe_2O_3, 44 per cent Fe_3O_4, originally discovered by Kato and Takei.[13] It is pressed, sintered, and then cooled in a magnetic field to impart directional magnetic properties through a precipitation reaction. Vectolite is hard and brittle, but can be finished by grinding. The Curie point is 450 C and its physical density is only 3.13 grams per cubic centimeter, making it particularly suitable for moving-magnet instruments. Applications over 100 C are limited by a large temperature coefficient of coercive force.

Cunife is a ductile and machinable alloy of 60 per cent copper, 20 per cent nickel, and 20 per cent iron originally discovered by Kussman and Scharnow.[14] It has pronounced directional properties along the direction of working, and its use is confined to sizes below 1/4-inch diameter because

of the 95 per cent cold reduction before aging required to develop optimum magnetic properties. The physical density is 8.6 grams per cubic centimeter. Its ductility has led to numerous special applications, for example, tape and wire magnetic recording.

Alnico VII is the highest coercive force member of the well-known precipitation-hardened Alnico family, containing 8 per cent aluminum, 18 per cent nickel, 24 per cent cobalt, 5 per cent titanium, 3 per cent copper, balance iron. Like all Alnicos, the material is cast or sintered to shape, producing a hard, brittle material which can only be finished by grinding. Its physical density is 7.34 grams per cubic centimeter. Cooling in a magnetic field develops the directional properties. This material replaces the now obsolete Alnico XII in applications where higher coercive force than Alnico V is required, for example, in permanent-magnet rotors for generators and motors.

Cunico is an alloy similar to cunife, containing 50 per cent copper, 21 per cent nickel, and 29 per cent cobalt, discovered by Dannohl and Neumann.[15] The nature of the precipitation reaction in both materials has been described by Geisler.[16] Cunico is ductile and machinable before final aging, and, unlike cunife, is nondirectional. It can be produced in strip, bar, or wire form, and is readily machinable on automatic screw machines. Its physical density is 8.3 grams per cubic centimeter. Quite a few applications have been found in instrumentation for cunico's combination of high coercive force and ductility.

Alnico VI lies between Alnico V and Alnico VII in both coercive force and induction. It contains 8 per cent aluminum, 15 per cent nickel, 24 per cent cobalt, 3 per cent copper, 1 per cent titanium, and balance iron; otherwise, it is similar to Alnico VII.

The design characteristics of high-coercive-force permanent-magnet materials have been reviewed briefly. The opportunities they present the design engineer will now be considered.

DESIGN CONSIDERATIONS

THE application of permanent magnets made rapid strides during the 1930's as engineers learned to exploit the higher coercive forces made available by the new precipitation-hardened magnet alloys. Large horseshoe magnets of martensitic alloy steel were replaced by much more compact and efficient Alnico magnets. This illustrates the principal direct benefit derived from higher coercive force materials; the fact that shorter lengths of magnet can be used, since the magnetomotive force produced by a magnet at an air gap is the product of the length of the magnet and the $-H$ co-ordinate of its operating point. An Alnico magnet can thus replace a chrome steel magnet over ten times its length, and higher coercive force materials lead to even shorter magnets.

An excellent example of the design possibilities this offers can be seen in the instrument magnet of a modern exposure meter, Fig. 4. The design engineer developed a magnetic circuit to utilize an Alnico magnet so short that it could be fitted within the small instrument armature, instead of outside in the more conventional manner illustrated by the older meter. The lighter weight and more compact design of this magnet contributed greatly to the superior features of this new instrument.

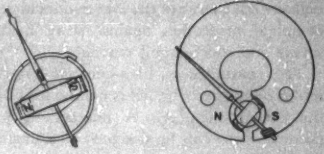


Fig. 4. Internal (left) and external (right) magnet instrument construction

In addition to the basic reduction in length of the magnet made possible by higher coercive force materials, there are a number of other possibilities which the designer can exploit.

There are situations in which it is sometimes necessary or desirable to magnetize a magnet before assembly into its final circuit. This frequently means that a high-coercive-force magnet is mandatory to resist its own self-demagnetization, or the mutual demagnetization of an associated magnet. A good example of this can be found in the magnetic suspension magnets used to float the disk of a modern watt-hour meter (Fig. 5). In this meter the problem of increasing friction as the bearings wear has been eliminated by supporting the rotating disk on a magnetic field, but it would be undesirable (and very difficult) to magnetize these magnets in place. A high-coercive-force cunico magnet makes possible a magnetic suspension system which can be magnetized before assembly, and then disassembled and reassembled at any time without remagnetization. The

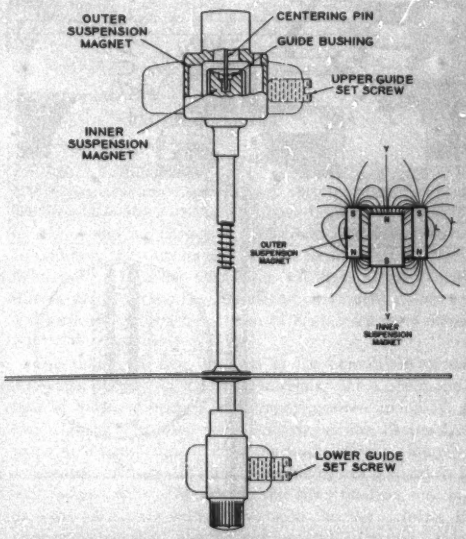


Fig. 5. Magnetically suspended watt-hour-meter rotor

high coercive force of the material incidentally also provides complete protection against stray fields from lightning surges and short-circuit currents.

The resistance of high-coercive-force materials to external demagnetizing fields can be an important feature to the design engineer. A magnet with a high intrinsic coercive force can be designed to withstand exposure to a demagnetizing field strong enough to reverse its induction, and still return to a useful operating point on removal of the strong knockdown field. This feature is useful in permanent-magnet rotors for generators exposed to short-circuit conditions, and for motors during starting. An interesting example can be given of a silmanal magnet designed to produce torque while exposed to a demagnetizing field of 5,000 oersteds. Although silmanal has a coercive force (H_c) of only 600 oersteds, so that in a 5,000-oersted field the magnet is operating well down in the third quadrant of the hysteresis loop, it is protected from permanent demagnetization by silmanal's intrinsic coercive force (H_{ci}) of 6,000 oersteds. This magnet is used in a unique gaussmeter, Fig. 6, which measures magnetic fields by balancing the torque produced by the magnet against an instrument spring. Stability in fields up to 5,000 gauss is essential for accuracy in this application.

Where magnets are used to produce repulsion, high-coercive materials can usually be applied to advantage. A magnet used for attraction reduces its self-demagnetization factor, so that low-coercive materials are satisfactory. In a repulsion system, however, the magnet must produce high flux under highly demagnetizing conditions. An example of a magnet-repulsion system which solved a difficult mechanical problem can be found in the cyclometer register of a modern watt-hour meter. This register is used to indicate numerically the meter reading by a series of drums printed with digits, in place of the usual pointers and dials. The problem of gearing each drum to rotate one digit when the drum to the right has completed one revolution was in itself simple, but it was complicated by the requirement that the torque necessary to turn the first drum must not suddenly increase at the point where it turns the second drum. This requirement was met by attaching a small cunife magnet beneath the first drum, and fixing another to the frame below it. As the drum approaches ten, the two magnets are forced into repulsion, thus storing magnetostatic energy. At ten the two magnets are over each other, and sufficient lost motion is provided in the system so that the magnets provide enough mechanical energy to rotate the second drum one digit as they release the energy stored in them during the approach to ten. In this way a reasonably uniform torque turns the cyclometer register through its entire cycle, even though the mechanical energy is all expended at one point. The use of magnetic-repulsion systems will certainly increase as higher coercive materials become available.

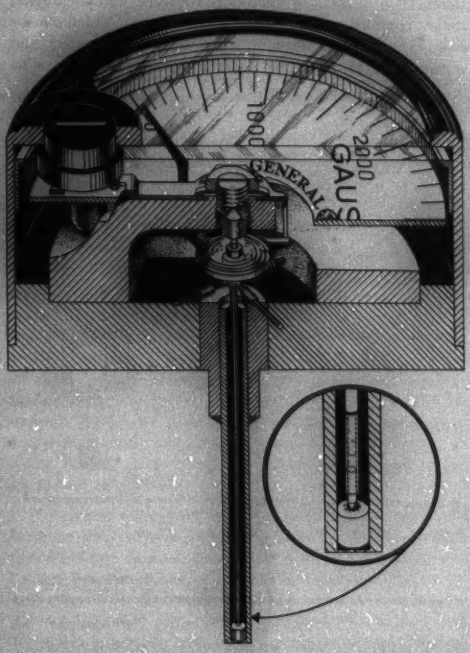
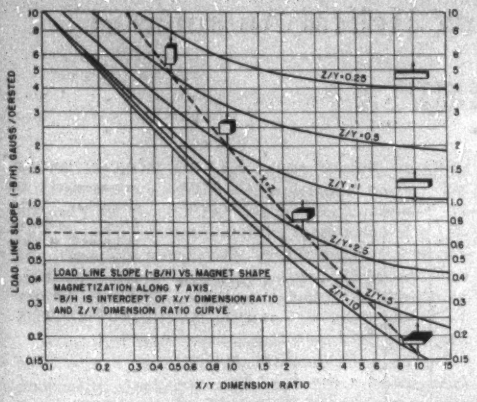


Fig. 6. Gaussmeter application of Silmanal magnet

The final design possibility which will be mentioned is the application of high-coercive-force materials to magnets of short lengths. As the ratio of the length of the magnet to its diameter approaches one, the magnet designer must turn to high-coercive-force materials to obtain reasonable flux outputs in the face of the high self-demagnetization factors of these shapes. For example, a cross-magnetized cylindrical magnet is a desirable shape for a moving-magnet instrument, to minimize the weight and moment of inertia of the rotor, and cylindrical rotors of Vectolite are widely used in moving-magnet aircraft instruments because of the high coercive force and low density of this material. A cross-magnetized cobalt-platinum cylindrical rotor is used in a high-sensitivity gaussmeter.

Since magnets for these applications do not produce flux in a gap, but create a magnetic field in space, the usual circuit analysis of the flux output is not readily applicable. For magnets used in shapes with a high self-demagnetizing factor, the best way to estimate the operating point of the magnet is by calculating the demagnetizing factor of an ellipsoid with the same dimension ratios as the magnet in question. Demagnetizing factors for the general ellipsoid magnetized along its major axes have been calculated by Osborne.[17] Cylinders or rectangular parallelapipeds have been found experimentally to agree within 10 per cent of these calculations for ellipsoids.

Fig. 7 is a convenient representation of this information useful for estimating the load line of a short magnet from its dimensions. As an example, consider a Vectolite magnet 1/2 by 3/4 by 5 inches, magnetized along the 1/2-inch dimension. The remanent induction can be determined as follows: From the X/Y and Z/Y dimension ratios, the



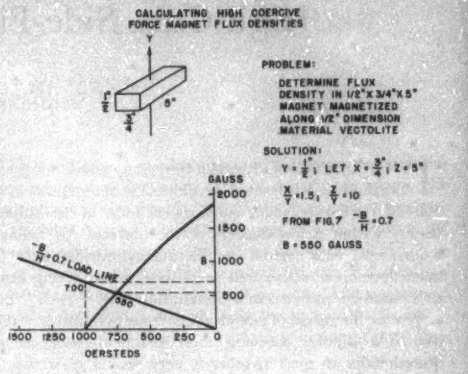


Fig. 7 (left). Load line slope (−B/H) for various magnet shapes based on ellipsoid approximation. Fig. 8 (right). Permanent-magnet design calculation using Fig. 7

load-line slope is found from the appropriate curve in Fig. 7. A load line with this slope is then constructed from the origin to intersect the demagnetization curve of Vectolite, and the remanent induction determined from this intersection, as in Fig. 8. This graphical construction allows the designer to determine rapidly how closely maximum-energy conditions are approached for various materials and magnet shapes. Modifications of this graphical construction can also be used to evaluate the performance of a magnet with an externally applied demagnetizing force.[18]

The characteristics of high-coercive-force permanent-magnet alloys have been reviewed and some of the opportunities and problems involved in their application have been considered briefly. This subject should become of increasing interest to the design engineer as continuing progress in material development makes available even higher coercive force permanent magnets.

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Heat-Sensing Cells

Little slips of glass coated with lead sulfide that can give 10,000 times as much sensitivity to certain infrared rays as previous laboratory instruments have been made available to science and industry by the Eastman Kodak Company. In addition, they are highly sensitive to all colors of visible light and on into the ultraviolet. Known as the Kodak Ektron Detector, the new photoconductive cells culminate a decade of research by a team of Kodak scientists under Dr. G. W. Hammer.

The cells were first unveiled at the convention of the American Society for Testing Materials. As a demonstration of the new cells, Kodak representatives exhibited a small box that emitted squeals whenever the Ektron Detector on it "saw" the bit of hot ash on the end of a cigarette. It also squealed loudly when a flashlight was pointed at it with battery cells so weak that the lamp filament scarcely glowed. A strong potential is seen for the detector in chemical processing plant operation and in complex electrical equipment.

High-Gain Side-Firing Helical Antennas

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ASSOCIATE MEMBER AIEE

THE ADVENT of ultrahigh-frequency television broadcasting has accelerated development of antennas in the 500- to 1,000-mc range which direct most of the radiated energy within a few degrees of the horizon. A helically wound coil and coaxial conducting cylindrical mast has been developed which will so radiate, while giving essentially uniform patterns in a horizontal plane.

Within the range of power gains from five and ten relative to a dipole, covering most practical cases, the required helix to mast spacing is very nearly given by the expression $S \cong \lambda/G$ if an arrangement is used having a helical conductor diameter of approximately 1/100 wavelength, a turn length of 2 wavelengths, and a pitch of 1/2 wavelength. A coaxial stack of five such bays, each with a power gain of five, excited equally and in phase, produces radiation patterns such as that of Fig. 1, having over-all power gains of 25 relative to a dipole, and main beam half-power widths of 2°.

The device radiates in a fashion similar to a transmission line having a spacing between conductors appreciable with respect to a wavelength. The line in this case consists of the helical conductor and its virtual image, a second helix internal to the cylinder. A traveling wave passes along the helix from the feed toward each end. If the length of helix turn is an integer number of wavelength, current in every

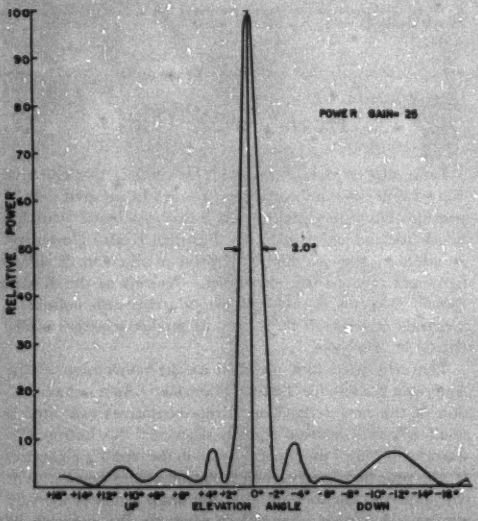

Fig. 1. Measured vertical pattern, on a power basis, of 5-bay antenna without special phasing for null fill-in or beam tilt

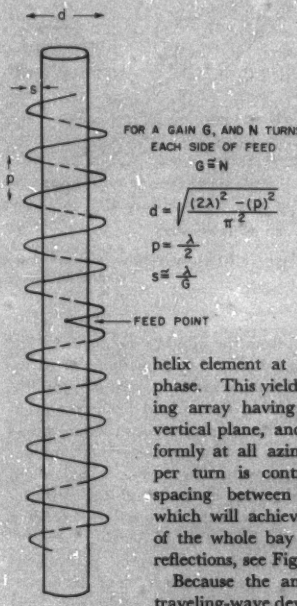

Fig. 2. Winding arrangement of single-bay side-firing antenna composed of concentrically disposed helical conductor and conducting cylinder

helix element at a given azimuth is in phase. This yields a broadside radiating array having high resolution in a vertical plane, and radiating nearly uniformly at all azimuths. The radiation per turn is controlled by choosing a spacing between helix and cylinder which will achieve adequate excitation of the whole bay without excessive end reflections, see Fig. 2.

Because the antenna is essentially a traveling-wave device with little reactive energy storage, a minimum problem is encountered in achieving the wide impedance bandwidth required. The frequency bandwidth over which the antenna maintains its beaming characteristic is limited by the gain attempted per bay. In commercial designs, choice of gain of five per bay is frequently made. This not only assures ample beaming bandwidth but permits a sufficient number of bay feeds for control of the stacking factor of multiple bay arrays to achieve downward beam tilt without appreciable beam breakup, and also for control of the depth of pattern minimums.

The absence of large reactive storages in accomplishing the necessary mode conversion from a coaxial line to cylindrical waves in space gives the device its unique characteristic in that it removes the necessity of critical adjustment of multiple circuit components having individual resonant characteristics. By balancing the number of elements fed in series and in parallel, the desired bandwidth and beam shaping is achieved with a minimum of complexity in the feeding networks.

Digest of paper 54-165, "High-Gain Side-Firing Helical Antennas for Ultrahigh-Frequency Television Broadcasting," recommended by the AIEE Committee on Television and Aural Broadcasting Systems and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 18-22, 1954. Published in AIEE *Communication and Electronics*, May 1954, pp. 135-8.

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Integration of High-Voltage Systems in Britain

D. P. SAYERS F. J. LANE

INTEGRATION OF high-voltage systems in Great Britain has proceeded in two well-defined stages. The first occurred about 1930, with the establishment of the Central Electricity Board and the construction of a 132-kv national grid system. The second stage is now in progress, with the construction of a new 275/300-kv super grid by the British Electricity Authority (B.E.A.), set up under the Electricity Act of 1947.

At the first stage the Central Electricity Board was faced with a large number of independent systems, a multiplicity of voltages, and several different frequencies. Systems with nonstandard frequencies were changed over to the standard 50 cycles at a cost of some £17 million, and all the important stations and systems were linked up through a national grid system, comprising 3,000 miles of transmission lines, mostly 132 kv, at an initial cost of £27 million. The scheme achieved a substantial reduction in the amount of spare generating plant, and helped to reduce operating costs by concentrating generation in the more economical stations.

An important provision in the trading relations between the Central Board and the many municipal and company undertakings, all of whom continued to own the generating stations and distribution systems, was that the cost of current to distributors at existing selected generating stations should not exceed what it would have been under independent operation. This had a significant effect on system planning, as it was financially advantageous for distributors to develop their own networks from existing supply points. Commercial settlements became more difficult as time went by, as they involved complex comparisons between "actual" costs and estimated "hypothetical" costs.

The second stage of integration was initiated by the Act of 1947, under which all the existing undertakings were superseded, and their assets transferred to the B.E.A., consisting of the Central Authority, responsible for generation and main transmission, and 14 Area Boards, responsible for distribution. The new structure of the industry has permitted an entirely new approach to many aspects of system planning. At the outset an important principle was instituted that a common bulk supply tariff should apply to all Distribution Boards (subject only to fuel cost adjustment in the different areas), and that development schemes should be settled on the basis of optimum over-all economy, irrespective of whether the costs fall on the Central Authority or the Distribution Board.

Soon after the new organization had been established an exhaustive study of future power requirements was completed, and the conclusion was reached that the existing 132-kv grid system needed major reinforcement, mainly on account of the increasing size of generating plant, the multiplicity of circuits, and the rise in short-circuit levels.

The B.E.A. decided that the best way of meeting the situation was the construction of an entirely new 275/300-kv grid system which would be, normally, the only means of interconnection between areas. One of the first steps was a study of future load growth, and the results are shown in Fig. 1 which illustrates the difficulty in long-range forecasting of future demand. The essential need was for increased interconnection capacity between areas, as the studies show that the margin of spare plant required to give the same security in all areas could thereby be reduced, with a substantial over-all saving in capital investment. A secondary consideration was that additional transmission capacity would permit the siting of new generating plant near the coal fields, where delivered fuel costs are low, and so lead to future operating economies.

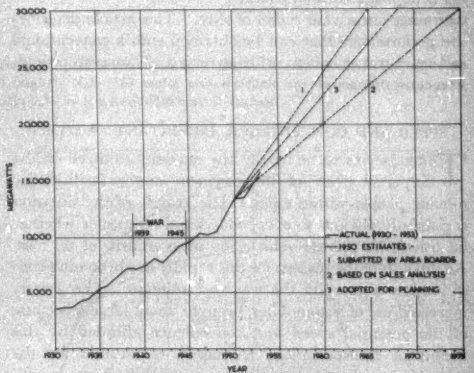

Fig. 1. Maximum demands 1930–75

The scheme as designed for 1960-61 will provide transmission capacities of up to 2,000 megawatts between certain areas. Double circuit lines are being used throughout, in order to make the maximum use of any line routes which can be obtained. All the lines are being equipped with twin conductors of two standard sizes, the smaller having a rating of 375 megavolt-amperes (mva) per circuit, and the larger of 550 mva per circuit. The towers for the latter are designed to permit uprating to 380/400 kv at a future date. The scheme is now under construction at a cost of £73 million, and involves a total of 2,500 circuit miles of lines, and 10,000 mva of transformer capacity.

Digest of paper 54-254, "Integration of High-Voltage Systems in Britain," recommended by the AIEE Committee on System Engineering and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1954.

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High-Speed Rapid-Transit Equipment

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The role that high-speed rail rapid transit can play in alleviating city traffic congestion is discussed. For instance, multiple-unit train facilities can be provided in the center mall of expressway constructions at a fraction of the expense involved in building the additional highways to handle the equivalent number of people in automobiles.

TRAFFIC congestion resulting from the increased use of vehicles on city streets has reached the point where drastic measures are needed to permit freer movement of people within the metropolitan area. One of the brightest hopes for relief is high-speed rapid transit operating on private rights of way. This article describes the performance that can be obtained with a conventional rail rapid-transit system utilizing recent advances in propulsion equipment.

SPEED AND CONVENIENCE, IMPORTANT FACTORS

THERE seems to be hardly any necessity to dwell on the desperate need for improvement in the facilities for moving people within cities. The gravity of the situation is painfully obvious to every individual no matter whether he travels by private vehicle, by mass transit, or on foot. An analysis of the reasons for this rapidly mushrooming condition serves to point the way to a solution. The greatly increased use of automobiles, brought about largely because of the potential speed and convenience afforded by this means of transportation, is mainly responsible for the worsening traffic situation. The automobile driver is willing to pay the relatively higher cost of personalized transportation as long as it gives him reduced travel time and more convenience than other forms of transportation.

It is reasonable to assume that if the same factors which make the automobile so desirable could be equalled by mass transit, more riders would prefer this transportation medium. The result would be freer movement of people within the city and less need for multiple expressway construction. Experience has shown the fallacy of expecting superhighways alone to provide the relief so sorely needed. By their very nature they invite more motorists to drive into already congested areas. As these swollen traffic streams leave the expressways and enter the business area, they only compound the surface confusion already existing there.

RAPID TRANSIT ON EXPRESSWAYS

IF A mass transit system is to provide the incentives needed to make people prefer it to the private automobile, it must be segregated from other traffic and designed to operate at speeds that will produce less travel time. If this is to be achieved, running speeds must be substantially higher than permitted for automobiles because of the necessity of making a number of passenger stops. Maintaining such schedules requires operation on private rights of way, either elevated, underground, or on grade-separated expressways. From the standpoint of community benefits the last named represents the most attractive alternative.

Two outstanding factors favor the expressway. One is the low cost of installing rapid-transit lines in the median strip of an expressway. The other is the efficient use such lines make of the space they occupy. For instance, a double-track rapid-transit line has a passenger-carrying capacity equivalent to seven 8-lane highways jammed with automobiles. The additional cost of providing a rapid-transit right of way in the median strip of the Congress Street expressway in Chicago, Ill., for example, is estimated at less than 5 per cent of the total cost of the project. This method of increasing passenger-carrying capacity represents a tremendous saving in community funds as compared to the expense of building additional expressways to handle a like number of people in automobiles. Moreover, rapid-

Full text of paper 54-252, "High-Speed Rapid-Transit Equipment," recommended by the AIEE Committee on Land Transportation and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954.

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Fig. 1. Lightweight rapid-transit train used in Chicago

Table 1. Assumptions Used in Determining Maximum Practical Performance

Car weight, light	40,000 pounds
Average passenger load	7,000 pounds
Average loaded car weight	47,000 pounds
Line voltage	600 volts direct current
Accelerating rate	3 miles per hour per second
Braking rate	3 miles per hour per second
Coasting	None
Leeway	5 per cent of time in motion
Station stop time	15 seconds
Rotary inertia	6,000 pounds
Friction formula	Davis, 2-car train
Profile	Level tangent track

transit riders do not add vehicles further to complicate the business area traffic situation.

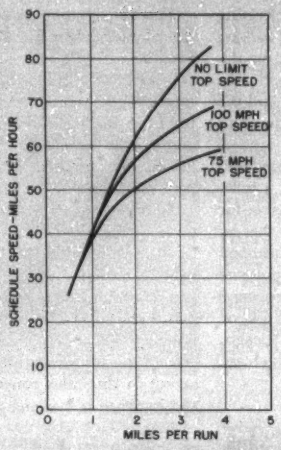
The automobile plays an important part in this proposal; in fact it will actually result in greater usage than if rapid transit were not available. This follows because the automobile can be driven from outlying areas to the nearest rapid-transit station by another member of the family thus making it available for family use all day long instead of being immobilized in the business area. Parking facilities adjacent to rapid-transit stations in outlying areas will provide convenient, low-cost parking when desired. This co-operative use of individual and mass transit facilities uses each type to best advantage and everyone benefits because over-all time for the journey is reduced, over-all cost is less, and fewer vehicles are operated in the congested business areas.

PERFORMANCE REQUIREMENTS

In order to determine maximum practical performance obtainable, a study was made using the modern Presidents' Conference Committee (PCC) type of rapid-transit car, see Fig. 1, as a basis of comparison. Table I shows the assumptions used.

The performance characteristics listed above are all obtainable with the PCC-type rapid-transit car having a gear ratio of 7.17 to 1 and 26-inch-diameter wheels.

After these boundaries had been established it was essential to know the best theoretical performance that could be obtained. This would indicate whether the ultimate in schedule ability was attractive enough to justify efforts to reach it. For this purpose it was assumed that an unlimited supply of power and propulsion equipment to use



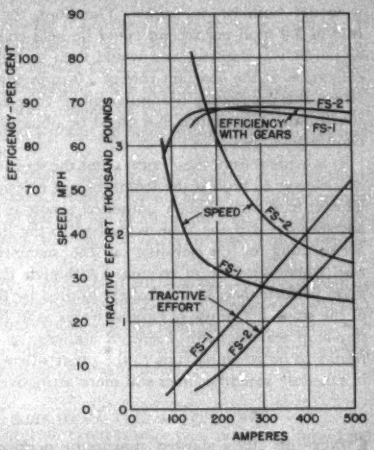
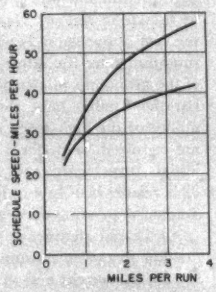


Fig. 2 (left). Maximum theoretical performance with acceleration and deceleration rates of 3.0 mph per second. Fig. 3 (right). GE-1247 motor characteristic curves on 300 volts, gear ratio 6.14 to 1, wheel diameter 28 inches



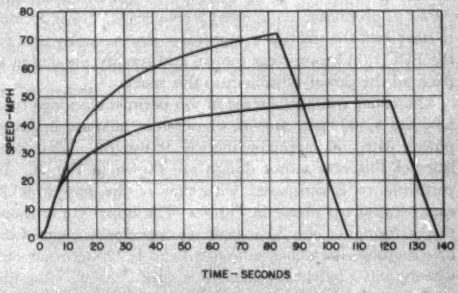
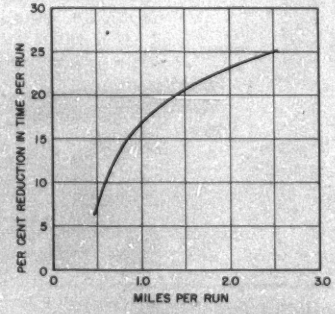


Fig. 4 (left). Upper curve: performance with new GE-1247 motor. Lower curve: performance of present PCC rapid-transit car. Fig. 5 (right). Speed-time curves for 1½-mile run. Upper curve: GE-1247 motor. Lower curve: present PCC rapid-transit car



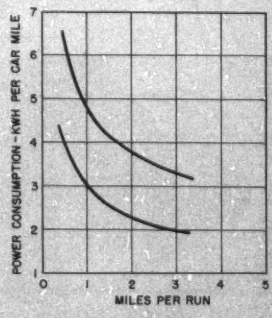


Fig. 6 (left). Saving in time possible with new equipment compared to PCC rapid-transit car. Fig. 7 (right). Power consumption. Upper curve: high-speed equipment. Lower curve: present PCC rapid-transit car

it would both be available. Therefore, the accelerating rate of 3.0 mph per second could be held constant as long as power was applied, and would then be followed by deceleration at the constant rate of 3.0 mph per second. In effect, this produces a triangular speed–time curve, and the maximum performance that could be obtained under such conditions is shown in Fig. 2.

It is evident from these curves that the schedule speed will not exceed 40 mph if the length of run is less than a mile. This is true even though unlimited power is available for acceleration and the train is pushed to the limit; that is, accelerating or decelerating at the maximum assumed rate whenever it is in motion. Although this represents good performance, it is definitely limited by the frequency of the stops. The use of express trains as in New York, or skip-stop service with *A* and *B* stations, as in Chicago, results in lengthening runs to the point where the increase in schedule speed becomes still more attractive.

NEW EQUIPMENT AVAILABLE

Since this study showed maximum performance to be worth striving for, an investigation was made to determine how closely it could be approached when actual equipment designs were used. For high performance it is extremely important to hold the car weight to a minimum. As far as propulsion equipment is concerned, it was decided to start with the traction motor frame size currently used for the PCC rapid-transit car motor, and modify the design to pack all the power possible into this space.

The result was an increase in top permissible speed from 5,000 to 6,500 rpm, and an 82-per-cent increase in horsepower, with no appreciable increase in weight. Characteristics of this new motor design are shown in Fig. 3. Its performance is compared with that of the present PCC rapid-transit car motor in Fig. 4. The upper curve shows the performance of a 2-car train equipped with eight of the new motors with a gear ratio of 6.14 to 1, 28-inch-diameter wheels, and a balancing speed of 80 mph. Comparing this with the theoretical curve (100 mph top speed) of Fig. 2, it is seen that the new design gives 83 per cent of the maximum performance obtainable under the assumed conditions in the range of 1 to 3 miles per run. This is a worthwhile improvement.

The lower curve in Fig. 4 shows present PCC rapid-transit car performance for the stated conditions, with gear ratio of 7.17 to 1 and 26-inch-diameter wheels. Performance of this car could theoretically be increased slightly by increasing wheel diameter to 28 inches. Where this change has been made, however, it has been accompanied by an appreciable increase in car weight for other reasons, and has actually resulted in a reduction of about 5 per cent in performance.

Another comparison of the difference in performance is given by the speed–time curves of Fig. 5. To reach a speed of 40 mph requires 40 seconds with the present cars, but only 15 seconds with the high-powered cars. The reduction in running time resulting from this sustained acceleration is shown in Fig. 6. Here is a powerful appeal to the prospective transit rider because he is interested primarily in getting to his destination as quickly as possible. The saving in time plus convenience of eliminating annoyance and expense of parking are certain to attract riders.

POWER CONSUMPTION

The use of increased motive power naturally leads to the question of the power consumption required to obtain the increased performance. Fig. 7 gives a comparison between the new and present equipment when performing as shown in Fig. 4. It is important to understand that the cost of operation is not proportional to the power consumption since the latter represents only 10 to 15 per cent of the annual fixed charges plus operating expense. Comparative studies have shown that the increased schedule ability of the high-speed equipment means that fewer cars are required to perform the service. As a consequence, initial investment and operators' wages are reduced. This results in a saving in over-all operating expense, the amount depending upon actual service conditions.

Additional significant increases in performance or reduction in power consumption can be obtained by reducing the car weight and streamlining the car body.

SERIES-PARALLEL CONTROL

A new control equipment, type *MCM*, has been developed to match the new traction motor, see Figs. 8 and 9. Its two motor-operated controllers use cam-

Fig. 8 (left). GE-1247 100-hp 500-volt d-c high-speed rapid-transit motor. Fig. 9 (right). Packaged control for high-speed rapid-transit car

Fig. 10. Artist's conception of Chicago's Congress Street expressway with rapid-transit tracks in the center mall. Parking facilities for transit riders may be provided in locations convenient to the rapid-transit stations

actuated contacts. One controller is used to set up circuits for series, series-parallel, and dynamic-braking connections. The other is used to regulate resistance in the traction motor circuits for acceleration and dynamic braking. The series-parallel arrangement of circuits is desirable with high-speed equipment because it provides flexibility of operation. If operating conditions do not require top speed, it is not necessary to accelerate to full parallel, and power can thus be saved. In addition, the operator can shut off from parallel and then return to series, thus maintaining reduced car speed without having continually to shut off and reapply power.

Extended dynamic braking, supplemented by four track brakes, eliminates the need for air brakes. Final stopping and holding of the car are accomplished by means of electrically operated drum or disk brakes mounted on the motor shaft.

High-powered equipment such as that just described, is being installed on two sample cars in Chicago where it will be tested in anticipation of the need for high-performance cars on the center mall of the Congress Street expressway, see Fig. 10, now under construction.

CONCLUSION

HIGH-SPEED rail rapid-transit can play an important part in preventing cities from getting enmeshed in traffic congestion to the point where they cease to function effectively. Facilities for multiple-unit trains can be provided in the center mall of expressway construction at a fraction of the cost required to build the additional highways capable of handling the movement of an equivalent number of people in automobiles. Here is a practical way to solve the traffic problem without bankrupting the public in the process.

World's Tallest Structure

Erection of the world's tallest man-made structure, a 1,572-foot television transmitting tower for Oklahoma City Station KWTV, was one of the most unusual fabricating and erection jobs.

The first section of the 1,323,392-pound tower was hoisted into place on June 14. Since then, additional 30-foot sections have been rising on the Oklahoma skyline, each carefully lifted into place by high-strength hoisting cables and wire rope slings. The triangular tower will give KWTV the greatest coverage pattern of any station in the Southwest. It was fabricated by the Ideco Division of Dresser-Stacy Company, Columbus, Ohio, and is being erected by the Mizell Construction Company of Ganado, Texas, in a record-breaking time.

The electrically operated boom inside the tower was co-ordinated by an intercom system. More than 14,000 feet of hoisting cable, produced by the Hazard Wire Rope Division of American Chain and Cable Company, was used.

The completed tower, which will be exactly 100 feet higher than New York's Empire State Building, is 12 feet on a side up to the 1420-foot level where it tapers in to the base of the antenna. It will rest on a base insulator made up of 21 four-inch-diameter porcelain tubes. The insulator is designed to withstand a crushing load of 11,200,000 pounds with a maximum working load of 2,800,000 pounds.

The first two sections of KWTV's massive 1,572-foot television transmitting tower are shown being hoisted into place. The boom at left, later placed inside the tower, was raised by push-button control

Small-Signal Parameters for Transistors

R. L. PRITCHARD

The commonly used sets of parameters are discussed briefly and it is shown how the performance of the transistor can be determined with equal facility from any of the sets that may be provided.

THE electric circuit properties of a transistor are very conveniently described by their linear small-signal parameters. For transmission-type applications, the performance of a transistor in a given circuit can be determined directly from these parameters.[1,2] In switching-type applications, it also is common practice to employ sets of small-signal parameters after first dividing transistor operation into three separate regions.[3]

In general, a 4-terminal network can be described by any one of six pairs of two simultaneous algebraic equations.[4-6] Under small-signal conditions, the four coefficients in each pair of equations are constants, independent of alternating voltage and current (although they may be quite dependent upon the direct voltage and current that is applied). These six sets of four coefficients each are the small-signal parameters. Note, however, that only four independent parameters actually exist. Corresponding to each set of parameters as described, several different equivalent circuits can be devised,[7] and the elements in such circuits also may be considered as parameters. Furthermore, for a transistor, which can be connected in three possible configurations, viz., grounded-base, grounded-emitter, and grounded-collector, the number of possible parameters is increased threefold.

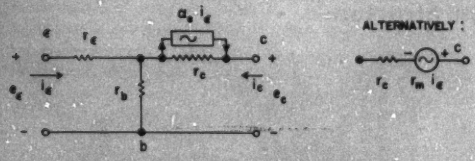


Fig. 1. Equivalent-T circuit for transistor

SMALL-SIGNAL PARAMETERS COMMONLY USED FOR TRANSISTORS

FOR point-contact transistors, it has been fairly universal practice to employ the parameters r_e, r_b, r_c and α_e(or r_m) of the T equivalent circuit[1] shown in Fig. 1. These parameters can be derived very simply from the impedance parameters [z] defined by the equations

$$\left.\begin{aligned} e_1 &= z_{11}i_1 + z_{12}i_2 \\ e_2 &= z_{21}i_1 + z_{22}i_2 \end{aligned}\right\} \quad (1)$$

(At low frequencies, these equations frequently are written with z_{ij} replaced by r_{ij}.) Thus, for the circuit of Fig. 1, $z_{11} = (r_e + r_b)$, $z_{12} = r_b$, $z_{21} = (r_b + \alpha_f r_c)$, and $z_{22} = (r_b + r_c)$.

On the other hand, for junction transistors, in addition to these equivalent-T parameters, two other sets of parameters have been used. These are the admittance, or [y] parameters, defined by the equations

$$\left.\begin{aligned} i_1 &= y_{11}e_1 + y_{12}e_2 \\ i_2 &= y_{21}e_1 + y_{22}e_2 \end{aligned}\right\} \quad (2)$$

and the series-parallel, or [h] parameters:

$$\left.\begin{aligned} e_1 &= h_{11}i_1 + h_{12}e_2 \\ i_2 &= h_{21}i_1 + h_{22}e_2 \end{aligned}\right\} \quad (3)$$

When a junction transistor is considered as an active semiconductor device just as the point-contact transistor, the same parameters are chosen for the former as for the latter.* When a junction transistor is considered analogous to an electron tube, the admittance parameters are chosen[9,10] (normally using the grounded-emitter connection.) On the other hand, when a junction transistor is studied *per se* and is found to have a low input impedance and a high output impedance, the series-parallel or [h] parameters (using the grounded-base connection) are chosen.* This choice of parameters also followed from a theoretical study of the physics of a junction transistor.[11]

The question of which one of these sets should be used is a matter of some controversy which it is wished to avoid here. Personal preference, familiarity, and viewpoint enter into the choice to a large extent.[12] In general the device designer will be interested in parameters that can be measured easily and that can be related simply to the physics of the device. On the other hand, the user normally will be interested in the utility of the parameters in determining device performance. It is this latter point with which this article primarily is concerned.

* This conclusion apparently was obtained independently by workers in a number of different laboratories early in 1952.

Revised text of a conference paper, "Over-all Viewpoint of Transistor Parameters," presented at the AIEE Summer General Meeting, Atlantic City, N. J., June 15-19, 1953, and recommended for publication by the AIEE Communication Division Committee.

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This work was supported by the Air Material Command, Signal Corps, and Bureau of Ships under contract *AF33(600)17793*.

However, a few brief comments concerning each of the three sets of parameters relative to junction transistors only might be of some value.

(*a*). *Parameters of equivalent-T circuit* (*derived from impedance parameters*). These parameters, which were the first introduced, are in fairly wide use. However, there are several distinct disadvantages to using these parameters for junction transistors. First of all, the parameters r_e, and in particular, r_b may vary with frequency in the audio-frequency range in which these parameters generally are measured.† For example, for a developmental model fused-junction *p-n-p* transistor, the following values were measured by the writer:

	low-frequency	1,000 cps	high-frequency
r_e	22	$\lvert 28+j4\rvert = 29$	31
r_b	830	$\lvert 400-j280\rvert = 490$	210

It is seen that the values of r_e and r_b at 1,000 cycles per second do not characterize adequately either the high- or low-frequency performance of this unit.

The second disadvantage is psychological. A high-quality junction transistor having a value of α close to unity may have a fairly large value of r_b, e.g., 2,000–3,000 ohms, by the very nature of its physical operation.† But a high base resistance r_b generally is considered to be objectionable. (For example, in a point-contact transistor, high r_b may cause short-circuit instability.[13]) In a junction transistor, high base resistance results in poor high-frequency performance.[14] However, since the base resistance that is important at high frequencies (r_b') may be much less than the low-frequency r_b, and since there may be very little relation between high- and low-frequency values of r_b, a high value of r_b at low frequencies is not necessarily objectionable.

Finally, it is very difficult to measure directly the parameters z_{11} and z_{21}, which require that the high collector impedance be open-circuited for alternating current while d-c bias still is provided. A tabulation of the conditions which must be satisfied for accurate measurement of each of the four parameters in the three commonly used sets is given in Appendix I.

(*b*). *Admittance parameters*. In the theoretical analysis of the junction transistor, the voltage-current relations are written most simply with the voltages as the independent variables; hence the admittance parameters are obtained.[15] However, when the resistance of the base region is taken into account in the usual manner, by addition of a lumped resistance r_b' (or $r_{bb'}$) to the base contact of the theoretical model, the transformation to obtain the admittance parameters for the modified transistor becomes very cumbersome. Also, when employing transmission-type measurements, it is very difficult to determine all of these parameters accurately, e.g., to determine y_{12} to even 10-per-cent accuracy it may be necessary to measure voltages of the order of 25 μv. See Appendix I. However, bridges have been developed to measure the admittance parameters.[16]

(*c*). Series-parallel parameters. The particular merit (and hence the reason for the introduction) of these parameters is the relative ease with which they may be measured. Thus, the low-impedance emitter circuit of the junction transistor is open-circuited while the high-impedance collector circuit is short-circuited. For example, in place of the y_{12} measurement mentioned, the corresponding measurement of h_{12} will make available approximately 10 or more times the voltage. See Appendix I.

† This was pointed out first by Early in reference 11, footnote 8, p. 1404.

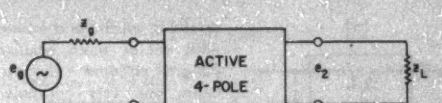


Fig. 2. Quadripole with generator and load impedance

APPLICATION OF SMALL-SIGNAL PARAMETERS TO TRANSISTOR CIRCUITS

The performance of a single transistor in a given circuit can be determined from any of the sets of parameters that may be given (so long as a complete set is given). Thus, for a simple transmission circuit such as shown in Fig. 2, the voltage amplification, power gain, input and output impedance, etc., can be calculated in terms of any of the parameters. For example, the available power gain G_{av}, defined as the ratio of the power delivered to the load Z_L to the power available from the generator, is given by the following equations

$$G_{av} = 4R_g g_L |e_2/e_g|^2 \tag{4}$$

where R_g and g_L are the real parts of the generator impedance Z_g and load admittance $Y_L \equiv 1/Z_L$, respectively, and where

$$\left.\begin{aligned} e_2/e_g &= z_{21}Z_L/[(z_{11}+Z_g)(z_{22}+Z_L)-z_{12}z_{21}] \\ &= -y_{21}Y_g/[(y_{11}+Y_g)(y_{22}+Y_L)-y_{12}y_{21}] \\ &= -h_{21}/[(h_{11}+Z_g)(h_{22}+Y_L)-h_{12}h_{21}] \end{aligned}\right\} \tag{5}$$

Note that the form of each equation is the same and that the same type of mathematical manipulations must be performed in any of the cases.

In a similar manner, the input immittance of the transistor Z_{in} or $Y_{in} \equiv 1/Z_{in}$ can be calculated from the following equations

$$\left.\begin{aligned} Z_{in} &= z_{11}-z_{12}z_{21}/(z_{22}+Z_L) \\ Y_{in} &= y_{11}-y_{12}y_{21}/(y_{22}+Y_L) \\ Z_{in} &= h_{11}-h_{12}h_{21}/(h_{22}+Y_L) \end{aligned}\right\} \tag{6}$$

The voltage amplification $A \equiv (e_2/e_1)$ can be determined from equations 5 above by setting $Z_g = 0$ (or by letting Y_g tend to ∞), in which case $e_g = e_1$. Finally, equations for the current amplification $K \equiv (-i_2/i_1)$ are as follows

$$\left.\begin{aligned} K &= z_{21}/(z_{22}+Z_L) \\ &= -y_{21}Y_L/[y_{11}(y_{22}+Y_L)-y_{12}y_{21}] \\ &= -h_{21}Y_L/(h_{22}+Y_L) \end{aligned}\right\} \tag{7}$$

Thus, if one set of parameters, e.g. [*h*] or [*y*], is given for a transistor, it is not necessary to convert these parameters to another set, e.g. to [*z*], in order to calculate circuit performance.

Small-signal parameters are also very useful in determining the performance of more complicated circuits, e.g., one

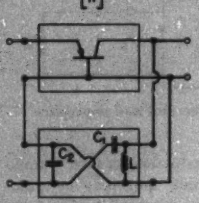


Fig. 3. Analysis of transistor Colpitts oscillator circuit by means of series-parallel [h] parameters

or more transistors combined with one or more auxiliary passive circuits. In such cases, one very convenient method of analysis consists of combining appropriate matrices, i.e., appropriate sets of parameters, to obtain an over-all matrix for the entire network. From this over-all matrix, circuit performance can be calculated in the same way as for a single transistor. Circuit analysis of this type has been used to some extent with electron-tube circuits, and there are a number of excellent references in the literature describing this technique.[17–21] It should be noted that in this type of analysis the choice of parameters is determined by the manner in which the component networks are combined. Hence, it might be convenient to employ any or all of the six possible sets of parameters. Interrelations among the six sets appear in the literature.[4–6‡,17,18] For convenience, the 3-way transformation between [z], [y], and [h], also is given here in Appendix II.

Circuit analysis by the combination of appropriate matrices may be illustrated by the circuit of Fig. 3, which shows a transistor in a Colpitts oscillator circuit. This circuit can be analyzed very easily in terms of the series-parallel [h] parameters of the over-all network. For example, the conditions for oscillation can be determined by setting the determinant $\Delta_h = (h_{11}h_{22} - h_{12}h_{21})$ of the over-all network equal to zero (corresponding to short-circuiting the input terminals and open-circuiting the output terminals). The parameters of the over-all network can be obtained simply by adding the series-parallel matrix of the transistor and that of the passive network. If the admittance [y] or impedance [z] parameters are given for the transistor, the [h] parameters first can be obtained in a straightforward manner, e.g., by employing the transformations in Appendix II. The [h] parameters for the passive circuit can be obtained by simple inspection, e.g., h_{11} is the impedance of the parallel combination of capacitors C_1 and C_2.

SUMMARY

It has been pointed out that small-signal parameters are very useful for describing the electric-circuit performance of a transistor. The three sets of parameters commonly used for transistors have been described briefly. Thus, for point-contact transistors, the impedance (z or r) parameters are widely used. With junction transistors, the admittance y and the series-parallel h parameters are used in addition to the z or r parameters. The question of which of the three sets should be used for junction transistors has been avoided, since personal preference and viewpoint may greatly influence the choice. However, several disadvantages of using the impedance parameters for the junction transistor have been pointed out. Also, the ease of measuring the h parameters relative to the y parameters by transmission-type measurements has been discussed briefly (with particular reference to the feedback parameter).

The principal purpose of this article is to point out that circuit performance of a transistor may be determined from any set of parameters that is given. Thus, voltage gain, input impedance, and similar quantities of interest may be calculated with equal facility with any of the sets. It is not necessary to convert from one set to another. On the other hand, for more complicated circuits comprising a transistor and passive network, one set of parameters may be more useful than another, depending upon the manner in which the transistor and passive circuit are combined. In this case, the circuit configuration actually determines which set is preferable. Consequently, it is emphasized that any of the sets of small-signal parameters that may be given for a transistor will be equally useful, in general, for determining circuit performance.

Appendix I. Conditions for Determination of Transistor Parameters by Transmission-Type Measurements

In order to determine the small-signal parameters of a transistor by a transmission-type measurement, a generator is applied to one pair of terminals and a load impedance is applied to the other pair, as shown in the upper part of Fig. 4. The load impedance Z_L must

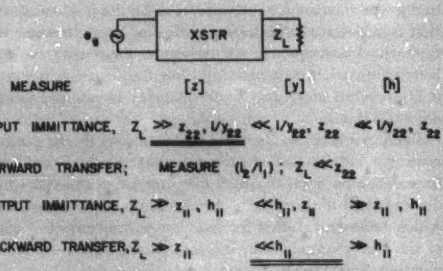


Fig. 4. Requirements on termination impedance for tansistor-parameter measurements

be small or large in magnitude depending upon whether a short-circuit or open-circuit measurement is to be made. In order to determine how large or small Z_L must be, it is convenient to express the conditions which must be satisfied by Z_L in terms of the transistor parameters, which generally are known to an order of magnitude. Results of such calculations are shown by the table of Fig. 4. Inspection of the table shows, for example, that in order to measure the open-circuit output immittance (impedance z_{22} or admittance h_{22}), the load impedance must be large compared both to short-circuit and open-circuit input impedance h_{11} and z_{11}, respectively.§ In Fig. 4, the two conditions that are underlined indicate two particularly difficult conditions to achieve in practice for junction transistors.

‡ Note, however, that Guillemin considers only passive quadripoles.

§ The subject of termination requirements for grounded-base operation only is discussed by G. Knight, Jr., R. A. Johnson, and R. B. Holt.[22] Note however that in their Table I, p. 987, the condition given for measurement of r_{22} is not correct although the condition for $1/r_{22}$ is substantially correct if $<<$ is replaced by $>>$.

Excluding the case of the open-circuit input impedance z_{11}, the most difficult measurement to make in general is that of the feedback, or backward transfer, parameter (measurement of voltage appearing across Z_L at the input terminals of the transistor when a voltage e_g is applied to the output terminals). This may be illustrated by means of a numerical example. A typical transistor will be assumed operating at a d-c bias of 1.0-milliampere emitter current and 4.5-volt collector voltage.|| For each of the three feedback measurements (z_{12}, y_{12}, h_{12}) a value of Z_L will be chosen to satisfy the inequality of Fig. 4 by a factor of 10, e.g., for z_{12} use $Z_L = 10z_{11}$. (Hence, the results obtained for the feedback parameters should be accurate to the order of 10 per cent.) Furthermore, a value of alternating voltage $e_g = 0.5$ volt will be assumed (small relative to d-c collector voltage). Under these conditions, the physical currents and voltages that must be measured for both grounded-base and grounded-emitter operation are given in the following table:

Feedback-Parameter Measurement, Assuming e_g = 0.5 volt

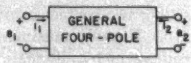
	[z]		[y]		[h]	
Grounded:	b	e	b	e	b	e
Use: Z_L	5,000	15,000	4	150	400	15,000 ohms
Measure:						
i_2	0.25	10				microamperes
e_1	125	250	13	25	125	250 microvolts

Note the very low voltages that must be measured in order to determine y_{12}. It also should be pointed out that if an accuracy of better than 10 per cent is required, the voltage available for the y_{12} measurement would be even smaller (since Z_L would have to be made smaller). On the other hand, for both z_{12} and h_{12} measurements the voltage available for increased accuracy does not decrease, unless it becomes necessary to decrease e_g (which also might be necessary in the measurement of y_{12}). However, the load impedance must be increased. For the grounded-base h_{12} measurement in particular, this obviously could be done very easily.

|| Parameters of a typical transistor at the given d-c operating bias might be, for example (grounded-base): $\alpha = -h_{21} = 0.975$; $r_0 = 1/h_{22} = 2\times10$-ohms; $h_{12} = 2.5\times10^{-4}$ ($r_0 = 500$); $h_{11} = 38$ ohms ($r_e = 25$). The corresponding grounded-emitter parameters are $y_{11} = 1/1{,}500$ mho, $y_{12} = 7\times10^{-4}$ mho, $y_{21} = -3.3\times10^{-2}$ mho.

Appendix II. Relations Between [z], [y], and [h] Parameters

Note polarity convention:



$[z] =$	z_{11}	z_{12}	$\frac{y_{22}}{\Delta_y}$	$\frac{-y_{12}}{\Delta_y}$	$\frac{\Delta_h}{h_{22}}$ $\quad$ $\frac{h_{12}}{h_{22}}$
	z_{21}	z_{22}	$\frac{-y_{21}}{\Delta_y}$	$\frac{y_{11}}{\Delta_y}$	$\frac{-h_{21}}{h_{22}}$ $\quad$ $\frac{1}{h_{22}}$
$[y] =$	$\frac{z_{22}}{\Delta_z}$	$\frac{-z_{12}}{\Delta_z}$	y_{11}	y_{12}	$\frac{1}{h_{11}}$ $\quad$ $\frac{-h_{12}}{h_{11}}$
	$\frac{-z_{21}}{\Delta_z}$	$\frac{z_{11}}{\Delta_z}$	y_{21}	y_{22}	$\frac{h_{21}}{h_{11}}$ $\quad$ $\frac{\Delta_h}{h_{11}}$
$[h] =$	$\frac{\Delta_z}{z_{22}}$	$\frac{z_{12}}{z_{22}}$	$\frac{1}{y_{11}}$	$\frac{-y_{12}}{y_{11}}$	h_{11} $\quad$ h_{12}
	$\frac{-z_{21}}{z_{22}}$	$\frac{1}{z_{22}}$	$\frac{y_{21}}{y_{11}}$	$\frac{\Delta_y}{y_{11}}$	h_{21} $\quad$ h_{22}

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Space Research Device

Minneapolis-Honeywell Regulator Company's Industrial Division in Philadelphia, Pa., has received a $15,000 contract from the Air Force Research Center at Cambridge, Mass., to produce an undisclosed number of "aerial electrometers" for ionospheric research. The aerial electrometer units were designed in the firm's Nuclear Engineering Laboratory.

The meters were described as supersensitive electronic devices to be used by Air Force scientists in research into the phenomena of electrical currents existing between the earth and 100,000 feet above it, or in the upper stratosphere. The research project is part of a continuing study being made by the Air Force of "terrestrial electrical field" existing between the earth and the ionosphere, which begins at a distance of 60 to 80 miles up.

Automatic Control for Electric Precipitators

H. J. HALL

THE VALUE OF automatic voltage control in maintaining maximum operating voltage and collection efficiency in gas-cleaning precipitators long has been appreciated. However, a practical system based on field investigation of actual operating requirements for optimum performance only recently has been developed.

The fundamentally new control system described is based on extensive field measurements of electrical operating conditions in a number of industrial precipitators, and on several years' field experience with an earlier and basically similar method using a mechanical spark-integrator. Contrary to previously accepted ideas, maximum collection efficiency usually occurs at operating voltages high enough to cause an appreciable amount of precipitator sparking, as illustrated in Fig. 1.[1] The optimum rate, corresponding to operation at the highest possible voltage compatible with the losses due to sparking, will vary somewhat with different types of precipitators, but it is typically between about 10 and 100 sparks per minute per precipitator section. The automatic control system therefore is based on measuring the average sparking rate, comparing this with the desired optimum rate, and using the difference or error signal to adjust the precipitator voltage to compensate for any change in the rate. Effective performance requires that the rate measurement be integrated or averaged over a period of a minute or more, that the spark control rate be adjustable within wide limits, and that the precipitator peak voltage be smoothly adjustable over a range of about two to one.

In the new system, the random and uneven precipitator sparking pulses are converted to standard pulses which then are integrated and smoothed to produce a d-c output proportional to the average sparking rate by means of the thyratron pulser circuit and integrating network, Fig. 2.

Digest of paper 54-175, "An Automatic Voltage Control System for Electrical Precipitators," recommended by the AIEE Committee on Electronics and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 18–22, 1954. Published in AIEE *Communications and Electronics*, May 1954, pp. 124–7.

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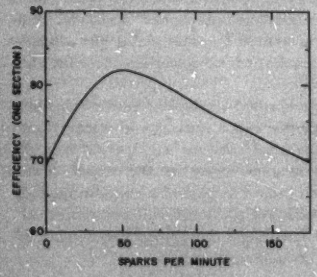

Fig. 1. Per-cent efficiency as a function of average sparking rate for a typical fly-ash precipitator

The indicating and control element is a contact-making microammeter actuating appropriate relay servo circuits which energize a motor-driven regulator in the primary circuit of the rectifier set. The basic system, however, also can be used with other control means such as, for example, a magnetic-amplifier servo arrangement.

The important characteristics and features of the system may be summarized as follows:

1. Electronic integrator and rate meter uses no moving parts and provides continuous indication directly in sparks per minute.

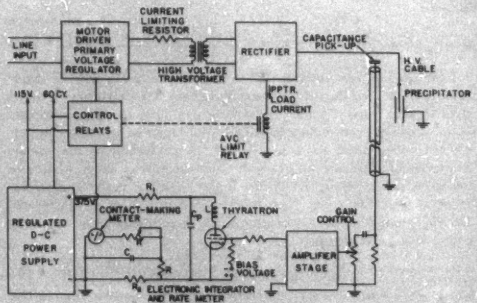

Fig. 2. Schematic block diagram of automatic voltage control system for electric precipitators

2. Control range may be field adjusted by simply setting two contact pointer knobs on the microammeter.

3. Ensures maximum utility of precipitator electric equipment by automatically maintaining full-rated power output when little or no sparking occurs.

4. Applicable to both new and existing rectifier sets energizing either single or multiple precipitator sections.

A pilot-model system installed about a year and a half ago on a large fly-ash precipitator has been in continuous satisfactory service without adjustment or operating difficulties. Performance monitored over a typical 14-day period showed a precipitator average corona power increase of at least 15 per cent above that which could otherwise be expected without frequent manual adjustment of the voltage by an operator. Important applications for automatic voltage control include the collection of fly ash, cupola furnace dust, cement dust, and dust from ore-sintering operations.

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Magnetic Frequency Multipliers

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ASSOCIATE MEMBER AIEE

WITH THE AVAILABILITY of high-quality magnetic core materials, it has become possible to develop very efficient magnetic frequency multipliers. The advance of the electronic arts in the development of computers and precise control systems has created the immediate need for frequency multipliers which can produce exact multiplication of frequencies in power levels ranging from milliwatts to a kilowatt. Magnetic frequency multipliers can be made to have characteristics superior to electronic multipliers in that they use no tubes, moving parts, or rectifiers.

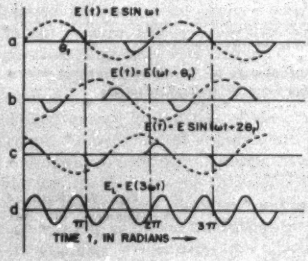

Fig. 1. Graphical illustration of frequency tripling. The contribution of load voltages of each supply is shown by solid line in curves a-c. The resultant load voltage is represented by curve d

Consequently, they are rugged, efficient, insensitive to temperature variations, and can deliver large quantities of power.

In the general case for frequency multiplication by an odd integer n, for which the supplies have a common ground and single load, the firing angle θ_f is determined by

$$\theta_f = \pi\left(\frac{n-1}{n}\right)$$

and the n distinct supplies are phased such that

$$E_1 = E_{max} \times \sin(2\pi ft)$$
$$E_2 = E_{max} \times \sin(2\pi ft + \theta_f)$$
$$E_3 = E_{max} \times \sin(2\pi ft + 2\theta_f)$$
$$\vdots$$
$$E_n = E_{max} \times \sin(2\pi ft + [n-1]\,\theta_f)$$

A graphical illustration showing the manner in which frequency tripling multiplication results is provided in Fig. 1. Thus, the firing angle for any of the three phases is fixed at $2\pi/3$ radians for optimum conditions. The *abc* curves in Fig. 1 represent the supply voltages in dashed lines and the contribution to load voltages of each supply in solid lines. The voltage across the load is the sum of the contributions of the separate phases, and the resultant is shown in curve *d*. It should be noted that each reactor fires only once during the half-cycle of its own supply.

The regulation of the load voltage and frequency is related closely to the regulation of the supply. The dynamic characteristics of the output can be improved considerably for load transients by the use of tuned output circuits. Since frequency multipliers operate on the saturation principle, it is necessary to limit the regulation of supply voltage and frequency. The overvoltage tolerance of frequency multipliers is determined mainly by the multiplication factor, the desired operating efficiency, and the output waveform tolerance.

The efficiency of frequency multipliers, as in all other power devices, is determined by the internal losses and the delivered power. A well-designed frequency multiplier will have in general power efficiencies in the range of 50–90 per cent over its useful load range. Waveform correction devices such as tuned output circuits decrease power efficiency since unwanted harmonics must be dissipated within the multiplier. For this reason it is desirable to design multipliers which do not require tuned output devices.

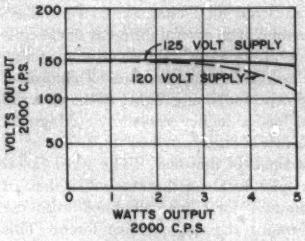

Fig. 2. Typical regulation characteristic for a quintupler

The authors have designed and built frequency multipliers with power ratings ranging from 1 to 300 watts and with multiplication values n ranging from 3 to 10. The application of the principles described in this design theory was used to obtain high efficiency and good waveform. Multiplier efficiencies having magnitudes as high as 90 per cent were achieved. An increase in weight and volume over rotary equipment which yielded equivalent power and frequency ratings was noted in all units, but the advantageous characteristics of reliability, long life, and almost no maintenance problems were evident for the magnetic frequency multipliers.

An example of the regulation characteristic for a quintupler is shown in Fig. 2.

Digest of paper 54-248, "Magnetic Frequency Multipliers," recommended by the AIEE Committee on Magnetic Amplifiers and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Scheduled for publication in AIEE *Communication and Electronics*, 1954.

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Flux Resetting of Several Magnetic Materials

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THIS ARTICLE deals with the flux resetting characteristics of several magnetic materials commonly employed in magnetic amplifiers. In this study the flux was forced to change under the influence of a constant external magnetizing force. The operation of a core employed in self-saturating magnetic amplifier circuits with high-impedance control windings approximates these conditions during the nonconducting half-cycle of supply voltage. The data collected therefore are readily applicable to studying this type of magnetic amplifier.

All tests reported were performed on gapless tape wound, toroidal cores made of commercially available materials. A special test circuit was built to drive the flux from saturation in one direction to saturation in the opposite direction with a constant current through one winding on the core. The induced voltage in another winding was displayed on an oscilloscope to give the rate of change of flux as a function of time. The oscilloscope display was photographed to provide a record of the waveshape and to allow the determination of peak and average rate of change of flux. Fig. 1 is typical of the photographs obtained.

Information was gathered for Deltamax, 65-Permalloy, Supermalloy, and Perminvar in several different thicknesses and anneals. In general, for a given magnetomotive force, in excess of the d-c coercive force, the rates of change of flux vary as would be expected, being higher as the material is made thinner or has a higher resistivity. Magnetic annealing reduces the rate of change of flux.

Fig. 2 is a plot of some of the data. The term excess magnetizing force, as plotted along the abscissa, is defined as the test magnetomotive force (as calculated from the current and turns) minus the d-c coercive force. This reduces the data to a basis which is more directly applicable to magnetic amplifiers. Hence, one can expect the highest gain from a self-saturating magnetic amplifier by choosing a core material which gives the highest value of the ratio of (rate of change of flux)/(saturation flux density times excess magnetizing force). This criterion is not precise for several reasons. First, the average rate of change of flux should be calculated for a half-cycle interval with the flux changing from saturation to some value slightly short of negative saturation. Second, the shape of the rate of change of flux versus time curve affects the shape of the gain curve and cannot be neglected. There is considerable difference in the waveshape even depending on the material thickness as illustrated by Fig. 3. It would be best if the rate of change of flux had a waveshape identical with the available reverse voltage on the rectifier.

It is very feasible that this material characteristic could be used to help evaluate core materials both by the user and the supplier. Variations among samples tested were so large that these data should not be used for design purposes. However, the trends seem to be clear and further studies of this sort may lead to more consistent and, therefore, more useful results.

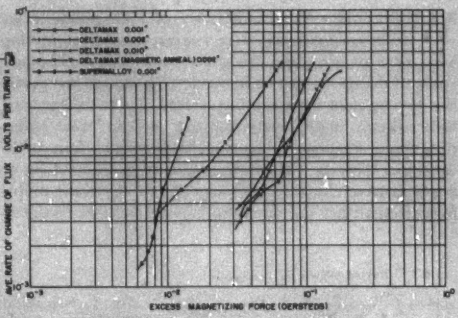

Fig. 2. Average rate of change of flux density versus excess magnetizing force for several materials

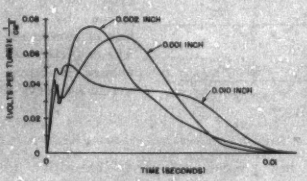

Fig. 3. Rate of change of flux versus time for Deltamax

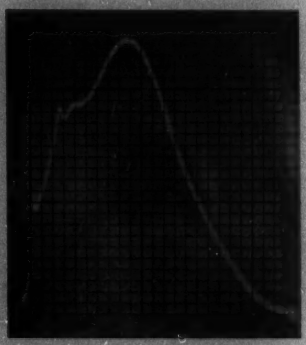

Fig. 1. Photograph of rate of change of flux versus time curve for a 65-Permalloy core of 0.005-inch-thick tape resetting in 0.044 second

Digest of paper 54-161, "Flux Resetting Characteristics of Several Magnetic Materials," recommended by the AIEE Committee on Magnetic Amplifiers and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 18–22, 1954. Published in AIEE *Communication and Electronics*, May 1954, pp. 111–14.

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Pulse Relaxation Amplifier: A Low-Level D-C Magnetic Amplifier

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A novel technique of magnetic amplification is presented in which the pulse relaxation amplifier performs as a signal reset and power gain without rectifiers. Its significant application lies in a region of signal sensitivity not heretofore available in magnetic amplifiers.

DEMAND for stable amplifiers to work at extremely low signal levels has attracted the attention of all who design and build amplifiers. The pulse relaxation amplifier (pra) is an outgrowth of this demand. It is essentially a magnetic amplier requiring no rectifiers and operating from a pulse power supply. Preliminary tests indicate a zero drift level less than 10^{-18} watt over a temperature range from −70 C to 140 C. This is compared to 10^{-8} watt attainable with conventional amplistats (self-saturating magnetic amplifiers). They are temperature limited primarily because of their rectifiers. The two greatest sources of drift in amplistats, variation in rectifier and magnetic core characteristics, have been eliminated in the pra.

The pra is not an amplistat, since by definition the latter achieves self-saturation by means of rectifiers in the output circuit. The pra employs the technique of short pulses separated by long relaxation periods. Flux reset in the core occurs during the relaxation periods. The pra operates from a pulse power supply and the pulse supply in turn from a sinusoidal power source. The magnetic core of the amplifier is driven into saturation by the power pulses. During the relaxation period, the core magnetization settles back to a level dictated by the control signal. The output power is determined by the amount of pulse remaining after saturation. Push-pull operation is achieved using a single magnetic core by comparing the alternate positive and negative pulses. Approximately the same gain and speed of response are realized in the pulse relaxation amplifier as in the amplistat.

Drift problems in the conventional amplistat are largely attributed to forward rectifier drop, reverse rectifier leakage, and variations in the magnetic characteristics between cores. By eliminating the rectifiers, reducing the number of operational cores to one per amplifying stage, and by operating this core in push pull, the pra has considerably less opportunity for drift. Regulation in the sinusoidal power supply both in magnitude and frequency are compensated. The circuitry is so devised that variation in saturation flux density and hysteresis loop width have negligible effect. Changes in hysteresis loop slope affect the gain only, not the level of drift.

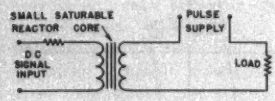
The pulse relaxation amplifier is basically a low-level device. As such, several stages of pra can be used to amplify a low-level signal bringing it to the microwatt level. Here conventional amplistats can be used to boost the power to higher output levels without further effect upon the drift. The concept of the pra suggests a wide variety of new functions that may be performed by magnetic amplifiers. These cover the fields of optical pyrometry, precision calorimetry, spectroscopy, geophysics, meteorology, differential thermometry, etc. Wherever extreme sensitivity is desired, the pra has an application.

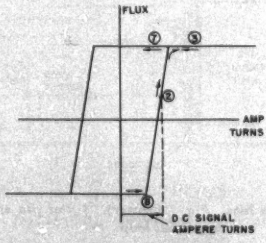
Full text of paper 54-198, "Pulse Relaxation Amplifier: A Low-Level D-C Magnetic Amplifier," recommended by the AIEE Committee on Magnetic Amplifiers and approved by the AIEE Committee on Technical Operations for presentation at the AIEE North Eastern District Meeting, Schenectady, N. Y., May 5-7, 1954. Published in AIEE *Communication and Electronics*, July 1954, pp. 245-9.

R. E. Morgan and J. B. McFerran are with the General Electric Company, Schenectady, N. Y.

THEORY OF OPERATION

Operation of PRA Input Stage. A simplified circuit of the pra input stage is shown in Fig. 1. Unlike a half-wave amplistat, this circuit employs no rectifiers. Also, the core size is much smaller than normally used in amplistats. Fig. 2 represents an idealized hysteresis loop (four straight lines) of the amplifier core characteristic. The axes of the loop are expressed in flux versus ampere turns, since no variation in core dimensions is introduced in this report





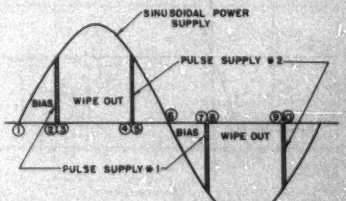
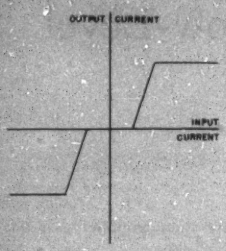


Fig. 1 (above). Simplified pra input stage. Fig. 2 (right). Hysteresis loop of pra input stage reactor. Fig. 3 (far right). Pulse and bias supplies relative to sinusoidal power source



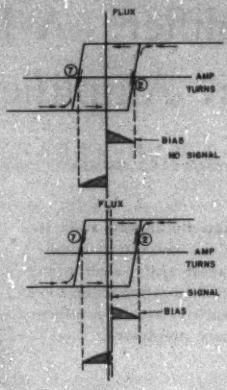


Fig. 4 (above). Input stage pra gain characteristic without bias. Fig. 5 (right). Pra input stage hysteresis loop with a-c bias

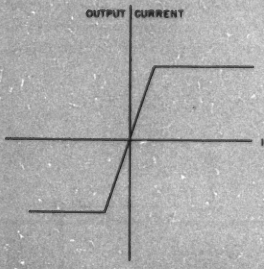
The encircled numbers on the loop establish a "time" correlation between the magnetic state of the core and the sinusoidal alternating voltage of the main power source. This is illustrated in Fig. 3 which shows the pulse supply relative to the main sinusoidal power source. Each number represents a "point" in time. Pulse width is 2° of the sinusoidal supply period.

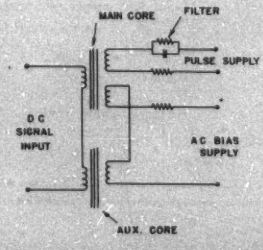
Following the operation in steps, start with point *2* on the right side of the hysteresis loop of Fig. 2. This starting point is established by the d-c signal ampere turns. The reactor is designed so that the pulse supply volt-time integral will swing the core flux over the entire range of the hysteresis loop. Therefore, the first portion of the pulse time is used to raise the flux level from point *2* to saturation. Full load current will then flow for the remainder of the pulse. The core remains saturated at point *3* until the beginning of the negative pulse. The total duration of the negative pulse is required to drive the core from positive to negative saturation. As negative saturation is just reached by the end of the pulse, no negative output current is obtained. The d-c signal returns the flux level in the core to point *2*. However, a definite period of time is required for the flux to accomplish this shift in level. This time is known as the relaxation period and represents the time between the end of one pulse and the beginning of the next.

A decrease in d-c signal ampere turns drops point *2* back to a lower value of flux in the hysteresis loop. A longer time is required for the positive power pulse to reach saturation, leaving less time for load current to flow. An increase in d-c signal ampere turns results in less time for the pulse to reach saturation and hence more time for load current to flow. In both instances the negative power pulse is completely absorbed in swinging the core from positive to negative saturation. A negative d-c signal causes the roles of positive and negative pulsed outputs to be reversed. A plot of output current, averaged during the pulse periods only, versus signal current provides the characteristic shown in Fig. 4.

Bias. Reference to Fig. 4 illustrates that the pra gain characteristic is bidirectional about the origin of the input and output axes. A low gain section in the characteristic appears at the origin due to the hysteresis loop width. This may be corrected by the addition of a cross-bias winding and supply to the pra. The bias must operate alternately positive and negative. It is applied most conveniently from a sinusoidal a-c supply. The bias supply adds ampere turns to the core in addition to the signal winding ampere turns. Fig. 5 illustrates the use of a-c bias. It is adjusted so that at points *2* and *7* the flux is set halfway between positive and negative saturation. This results in the flow of load current during both positive and negative pulses with a net output of zero. When a small d-c signal is applied in addition to the bias, points *2* and *7* are shifted accordingly, and a net output occurs due to oppositely directed control on both positive and negative pulses. Fig. 6 shows the gain characteristic with bias applied.

It is important to note that the net output represents the difference between the average currents during the pulses only. The small currents which occur during the relaxation period are not passed on to the following amplification stages. These currents are the result of the flux resetting voltages induced in the power winding. They may be ignored. A circuit composed of linear resistive and nonlinear reactive components and with an a-c supply having a zero average component cannot produce rectification. The net current averaged over the pulses and re-





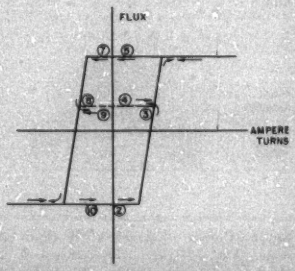
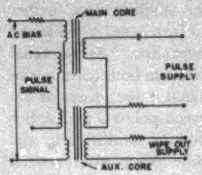


Fig. 6 (left). Pra input stage gain characteristic with bias. Fig. 7 (center). Input pra stage circuit. Fig. 8 (right). Pra interstage hysteresis loop

laxation periods must be zero. Although a net current difference may occur between the pulses, this is compensated by an equal but opposite difference during the relaxation periods. Since the pulse magnitude is many times larger than that during the relaxation period, only the pulses are passed to the following stages.

So far loading effects on the pra circuit through transformer coupling have been ignored. In a practical application of the pra principle, a means must be provided for achieving operation without loading through transformer coupling. The circuit for accomplishing this is shown in Fig. 7. Two cores are used instead of the previous single core. The added core acts in an auxiliary capacity, not in a manner whereby its characteristics are compared with those of the main core. The power winding circuit includes a filter element composed of resistor and capacitor. This acts as a high impedance to the slowly varying signal and bias supply induced voltages. However, to the pulse supply voltage, the filter is effectively a short circuit. The signal windings and bias windings are connected such that the induced voltages due to one supply cancel out in the windings of the other.



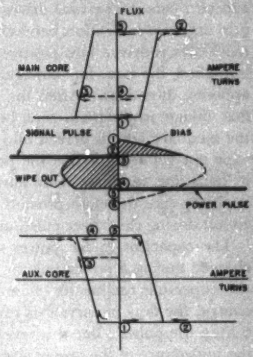


Fig. 9 (above). Pra interstage circuit. Fig. 10 (right). Time flux condition for pra interstage

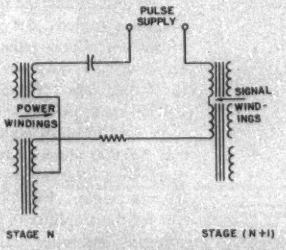
OPERATION OF PRA INTERSTAGES

For additional stages of pulse relaxation amplification an additional pulse power supply operating in time displacement relative to the original pulse supply is needed. This permits one supply operating in conjunction with the power winding of the previous stage of pra to set the signal flux level. A short time later the second pulse supply acting through the power winding causes the core to saturate and power to be delivered to the following stage signal winding. The power winding of this stage is connected to the original pulse supply. Summarizing, the interconnection of several stages of pulse relaxation amplification requires two pulse power supplies which are connected between alternate pra stages and furnish their pulses in alternate sequence. Fig. 3 shows the pulses of both supplies in time relation to the sinusoidal power. The pulses of one supply are between *2* and *3* and between *7* and *8*. Those of the other supply are between *4* and *5* and between *9* and *10*.

Consider an interstage of pra whose control signal is, instead of the steady d-c of the input stage, a pulsed signal. Other than this the circuit of Fig. 1 applies and may be used for a description of the operation. The magnetic changes of the core are shown on the hysteresis loop of Fig. 8. At point *2*, the flux is at negative saturation and zero ampere turns. This is the residual condition left by the preceding negative power pulse. The signal pulse applied at this point has sufficient amplitude and duration to make the transition to point *3*. At point *3* the signal pulse is removed. The flux remains unchanged until the beginning of the power pulse. At point *4* the power pulse is applied driving the core into positive saturation. Only a portion of the power pulse is required for this purpose, leaving the remainder for output. After the power pulse is over, the core drops back to the residual condition of zero ampere turns at positive saturation. A similar sequence is followed by the negative signal and power pulses.

The loading effects due to transformer coupling of the signal and power windings must also be considered in the pra interstages. Fig. 9 shows a pulse relaxation interstage amplifier designed partially to eliminate the loading effect of the pra and partially take advantage of it. Two cores, a main one and auxiliary, are used. Both cores have common signal and bias windings. The power winding links both cores while a "wipe-out" winding links only the auxiliary core. Induced components of signal voltage appearing in the power windings of the main and auxiliary cores buck out one another. The bias and wipe-out voltages are applied to their respective windings through large value resistances, so that these circuits contribute very little to the loading of the other windings and their circuits. Although these circuits are loaded by the presence of the signal winding circuit, their voltages are applied over long periods of time. The necessary flux reset is realized in this manner.

Referring to Fig. 10, a hysteresis loop of the auxiliary core is drawn with the ampere turns scale reversed so that a simultaneous comparison between it and the main core loop



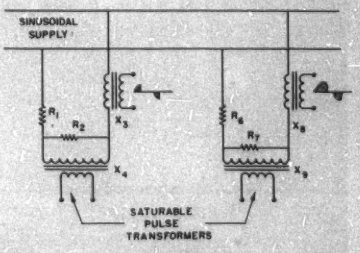


Fig. 11 (left). Interconnection of pra interstages. Fig. 12 (right). Power supplies

can be made. The bias drives the auxiliary core further into negative saturation between points *1* and *2* while the main core is driven into positive saturation. As the signal is applied, the same flux change occurs in both cores but in opposite directions. After the signal pulse, there is no flux change in the main core, between points *3* and *4*, but the auxiliary core is driven into positive saturation by the wipe out voltage. When the positive power pulse occurs, it finds the auxiliary core already in saturation. The auxiliary core therefore presents no impedance to the load circuit during the power pulse, only during the signal pulse.

The capacitor in the power winding becomes partially charged during a power pulse. After the pulse has ended, the capacitor retains its charge. In attempting to discharge, the flow of current is reversed from that occurring during the pulse. But this reversed current is opposed by the impedance of the power winding. The capacitor voltage decays only slightly. Meantime, sufficient volt-seconds are applied to the core by the capacitor to cause it to swing from its saturated state to saturation of the opposite polarity. Unfortunately, the signal pulse which follows finds the core already in saturation. It can do no more than drive the core further into saturation. Thus all control is lost. By changing the polarity of the windings, control is regained. However, the sense is now altered. The signal pulse drives the core in the opposite direction and from the opposite state of saturation than was previously done. The power pulse, however, is still acting in the same direction. Conceivably a large signal pulse could return the core to the state of saturation existing before the capacitor volt-seconds were applied. But this core state, in the previous signal connection, was obtained from a small signal pulse. Conversely, a small signal pulse in the new mode of operation sets the core to the same point as a large signal pulse in the previous mode. Thus a small signal results in a large output and a large signal results in a small output. The sense has been changed. Since the pra operates in push-pull, the net output between positive and negative pulses is still the same as obtained with the previous connection. Added stability is realized by this new mode of operation.

ADDITIONAL CIRCUIT CONSIDERATIONS

Multistage PRA Operation. Pra stages may be cascaded together until a signal is increased to a sufficient level that it can be amplified by more conventional magnetic means. Fig. 11 illustrates the interconnection of two interstages of pra. Transition from the pra to other means of amplification requires discrimination of the pra output pulses.

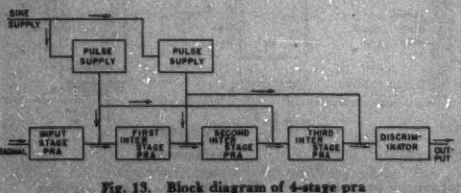


Fig. 13. Block diagram of 4-stage pra

Although the pra positive and negative pulses may differ in width as a function of the control signal, the average current over both the pulse and relaxation periods must still be zero. Thus the discriminator must take the difference in currents occurring during the pulse periods, and must eliminate those occurring during relaxation periods. The discriminator, rectifier or amplistat[4] type, permits the pra output to be interpreted for instrumentation or further amplification.

Pulse Supply. Consistent with popular application requirements the pulse supplies are of a static magnetic type, operating from a sinusoidal power base. Fig. 3 illustrates the dissection of the sinusoidal voltage of the main power source. The pulses of one pulse supply occur at 45 and 225°, while those of the other pulse supply occur at 135 and 315°. The relaxation period between pulses is not critical in its duration. Each pulse is approximately of 2° (100 microseconds in a 60-cycle source) duration. Much of the remaining portion of the sine wave is used to obtain bias and wipe-out voltages.

Fig. 12 shows the circuit used to obtain the pulse voltages. It is composed principally of transformers which are alternately saturated positive and negative. Returning to the sine wave of Fig. 3, the first 45° of the sine wave voltage are held off by X_3. When X_3 saturates the power is transferred from X_3 to the circuit made up of R_1, R_2, and X_4. X_4 is a transformer having a small core and few turns. It saturates after only 2° of angle, leaving the remaining portion of the half-cycle to be dissipated in resistor R_1. The secondary voltage of X_4 constitutes one pulse supply. The other supply pulse is achieved by similar means from X_9. X_8 is designed to hold off the first 135° of the sine wave voltage, after which the circuit composed of R_8, R_7, and X_9 receives the power. X_9 saturates rapidly so that its secondary voltage constitutes the other pulse supply. Also shown in Fig. 12 are the bias voltages and their waveforms.

The outstanding advantage of a magnetic-type pulse supply for the pra lies in the fixed volt-second integral provided by the pulse supply transformers. Regulation of voltage and frequency in the sinusoidal supply may alter the pulse shape, but not the pulse integral. Since the pra cores each require fixed volt-second values to swing the flux over their saturation range, the fixed pulse integral contributes much to the amplifier stability.

CHARACTERISTICS OF 4-STAGE PRA

Gain. A multistage pra with a d-c input and output was built and tested. It consisted of an input stage, three interstages of pra, pulse power supplies, and rectifier discriminator for output. Fig. 13 shows a block diagram of the 4-stage pra. It was designed to operate from a 115-volt 60-cycle power source. The resistance of the input stage was 50 ohms while that of the discriminator output was 200,000 ohms. Deltamax toroidal cores of half-inch diameter by 0.0005-square-inch cross section were used in the pra stages. Fig. 14 shows an over-all gain characteristic for the amplifier in terms of average volts output versus average volts input. Inasmuch as the input and output resistance levels are different, the over-all amplifier voltage

gain has less significance than an over-all power gain. If such is computed from the linear portion of the gain characteristic using the resistances of input and output circuits, the power gain is of the order of two million. The linear portion of the amplifier will accommodate a maximum input signal of 10^{-11} watt while delivering an output in excess of 10^{-4} watt.

Speed of Response. Speed of response in the pulse relaxation amplifier is a function of the input stage time constant and the interstage pulse delays. The time constant of the signal winding in the input stage is inherently low. This is principally the result of using small core sizes, which generally give quicker response. Between stages of pra, quarter-cycle pulse delays are involved. That is, the second stage will not respond until its pulse which occurs 90° after the first stage pulse. Pulse delay is also involved in the input stage of the pra. However, here it may take any value from 0 to 360° of the sinusoidal supply frequency. Assuming an average input stage delay of 180°, the response of a multistage pra circuit is the sum of the time constant of the input winding and the product of the number of stages plus one times a quarter period of the sinusoidal power supply.

Drift. The results of preliminary drift tests are presented here. These tests were made to estimate the influence of temperature and power supply variations on output and gain of the pra. The drift level was determined by observing the output of the amplifier with the input signal held at zero. An input signal, which when amplified gave the same magnitude of output as that given by the drift level, defined the minimum signal level of the amplifier. Recordings were made over a 2-week period of the pra output. Power supply voltage was varied ±30 per cent and temperature for the first stage was cycled between −70 C and 140 C. Maximum drift during this period was 10^{-10} watt. The gain characteristic showed complete continuity. A check of gain stability showed variations of 10 per cent for power supply frequency variations of 10 per cent.

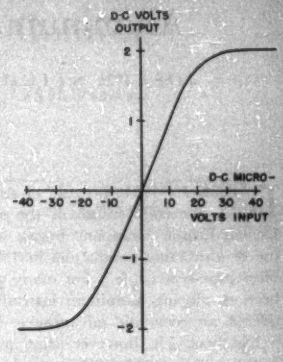


Fig. 14. Gain characteristic of 4-stage pra

CONCLUSION

Circuit constants and variations upon the circuit types for the most part have been omitted. The purpose of this article has been to present a novel technique of magnetic amplification, therefore detailed circuit information has been minimized. The pulse relaxation amplifier realizes the functions of signal reset and power gain, requirements of any magnetic amplification scheme. Its significant application lies in a region of signal sensitivity not heretofore available in magnetic amplifiers.

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Electronic Brain Assembled in Window

Philadelphia pedestrians watch the construction of an electronic brain, UDEC II, take place in the showcase window of the Burroughs Corporation, Electronic Instruments Division. UDEC II (Unitized Digital Electronic Computer) will be operated in the window to provide the only major computation service available on a rental basis in the Greater Philadelphia area. The new computer, although reconstructed from the company's previous 3-year-old computer, will have six times the memory capacity of its predecessor, an improved system of internal logic, and an increased speed of computation. To be utilized as an automatic, high-speed digital computer, UDEC II contains 648 building blocks or electronic chassis connected together with more than 5 miles of cable. The C-shaped electronic brain is 7 feet high and 60 feet long

Aluminum Conductors for Pipe-Type Cable

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EARLY IN 1951, because of an existing shortage and the uncertain future of the supply of copper, The Detroit Edison Company began actively to consider the use of aluminum conductors in 138-kv high-pressure gas-filled pipe-type cable. For many years, the company had been employing aluminum instead of copper wherever it offered an economic advantage. In these considerations it had been felt, however, that in any change-over from copper to aluminum conductors the field of the extra-high-voltage underground cable would be one of the last in which such a conversion should be attempted. Nevertheless, realizing that with the ever-expanding extra-high-voltage underground cable system of the company, the day might come when copper is not available for a new line or when aluminum shows a definite economic advantage over copper, the decision was made to investigate the feasibility of using aluminum instead of copper for this purpose.

In order to obtain a definite answer for some important questions, a major investigation was undertaken as a co-operative effort between The Detroit Edison Company and the General Cable Corporation. For this purpose the latter designed and manufactured an experimental length of cable with an aluminum conductor that would be the equivalent in carrying capacity and would be installed in the same size pipe as that presently used in the Detroit Edison System which employs a 1,500,000-circular mil-(CM) copper conductor. Specimens for this experimental cable have been used in many tests conducted in the laboratories of the manufacturer and of the user.

There is every indication that from a technical point of view a 2,250,000-CM aluminum conductor could successfully take the place of the 1,500,000-CM copper conductor, employing the same size steel pipe, based on a study of the current-carrying capacity, of dielectric strength, and ionization starting potentials on cables subjected to such treatment as might occur during service operation, and of restraint tests carried out to determine the capacity of the pipe to accommodate the aluminum-conductor cable and the forces that might be exerted on joints and terminals. From an economic point of view, the indication that pulling lengths could be doubled as far as pulling-in operations are concerned might lead to interesting developments resulting in possible savings.

Digest of paper 54-225, "Studies Relating to the Use of Aluminum Conductors for Pipe-Type Cable," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1954.

Joseph Sticher and R. H. Hiester are with The Detroit Edison Company, Detroit, Mich.; Louis Meyerhoff is with the General Cable Corporation, Bayonne, N. J.; and M. H. McGrath is with the General Cable Corporation, Perth Amboy, N. J.

The authors are indebted to many of their associates in The Detroit Edison Company and the General Cable Corporation who have contributed so generously to these studies and in the preparation of the material for publication; they wish to thank specifically W. H. Cortelyou and J. Bower of General Cable, and T. H. Roughley, W. C. Franke, and C. A. Anderson of Detroit Edison who were in direct charge of certain major phases of the experimental work.

Specific conclusions drawn from these studies on 2,250,000-CM segmental aluminum-conductor cable are

1. Experimental determination of the a-c resistance indicates that this cable has lower conductor losses than are average for a copper conductor with equal d-c resistance, but for the time being it is safer to use for aluminum the loss equations which have been established for copper. It also is evident that the oxide film on the strands is not adequate insulation between segments, and that the use of paper insulation between segments of aluminum cable is as necessary as with copper.

2. With respect to the capacity of the pipe to accommodate the larger aluminum conductors, it is indicated that there is less danger of jamming during pulling-in operations with the aluminum conductors, and that the cables with the 2,250,000-CM conductors would have a better chance of being pulled-in in triangular configuration in the 8-inch pipe than would the cables with the 1,500,000-CM conductors.

The maximum compressive force developed, prior to snaking of the conductors during the heating periods of the cable, is of the order of 5,000 to 6,000 pounds and is not expected to exert an excessive thrust on joints and potheads.

Excessive bending of the cable as a result of snaking due to conductor-temperature rise is not likely to occur.

It is indicated that once snaking occurs, subsequent snaking will flex the cable in the same location. It is concluded from extensive flexing tests that no significant softening of the insulation will result from this cause.

3. On the basis of stress-strain characteristics determined experimentally it is indicated that the ratio of the maximum allowable pulling lengths for aluminum-conductor cables of the same current-carrying capacity as the 1,500,000-CM copper-conductor cables is approximately two.

4. From high-voltage time tests on cable samples that had been subjected to the restraint test, the tension test, and the cold bend test, and from the dissection of these samples, it was concluded that neither the dielectric strength nor the mechanical uniformity of the insulation was significantly affected by this treatment.

5. On the basis of ionization–starting potential determinations made under various conditions that might occur during service operation, it is concluded that there is no significant difference in the performance of the copper-conductor and aluminum-conductor cables.

6. Preliminary results of an extensive study of the joining of aluminum conductors by means of compression connectors, of soldering, of various methods of welding, and of a combination of using compression connectors with a welding process have indicated that the use of compression connectors holds promise.

Closed-Loop Automatic Phase Control

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IN DEVICES such as the sweep circuits of a television receiver, it is necessary that not only the frequency of an oscillator but also its phase be controlled by an incoming signal. This article describes the design of a closed-loop system for phase control of an oscillator.

EQUIVALENT CIRCUIT

A TYPICAL instrumentation for such a device is shown in Fig. 1. The incoming signal e_i and the signal locally derived from the oscillator e_o are multiplied together by means of the multiplier. The output of the multiplier has components at the sum and difference frequencies. The low-frequency component is a function of the instantaneous difference of the phase $\phi_i - \phi_o$ of the oscillator and the incoming signal. The high-frequency components are rejected by the low-pass filter and its output controls the frequency of the local oscillator in such a way that the phase difference is reduced to a constant value. Thus the frequency of the incoming wave and the local oscillator are nade the same. The phase difference may be made as small as required by proper design.

The system consists then of a phase detector, which may be instrumented in many other ways than that shown in Fig. 1. The phase detector is followed by a low-pass filter; the output of which controls the frequency of the local oscillator, usually by means of a reactance tube. From the standpoint of analysis, any form of instrumentation such as in Fig. 1 may be represented by a phase-equivalent circuit such as shown in Fig. 2. The oscillator is represented as an integrator, since the quantity controlling it is phase and its output is frequency. Phase is the time integral of frequency. The representation of the system in the closed-loop form shown in Fig. 2 allows techniques of servomechanisms analysis to be used in optimizing the design of the system.

ANALYSIS

IT MAY be shown that the static accuracy of the system is directly related to the loop gain; furthermore, the loop gain influences the transient response of the system and the pull-in range. As in all closed-loop systems, the tendency to hunt when the loop gain is high must be suppressed. This is most expeditiously done by analysis of the system in the frequency domain and synthesis of the required equalization filter to provide adequate phase margin at a loop gain of unity. The filter may be optimized by

Digest of paper 54-268, "Closed-Loop Automatic Phase Control," recommended by the AIEE Committee on Electronics and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Published in AIEE *Communication and Electronics*, September 1954, pp. 375–81.

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This article is the result of research on synchronizing of pulse-code modulation receivers carried on under the support of the U. S. Army Signal Corps contract number *DA-36-039-SC-5416* and is a digest of Technical Report Number 9, July 1953, of that contract.

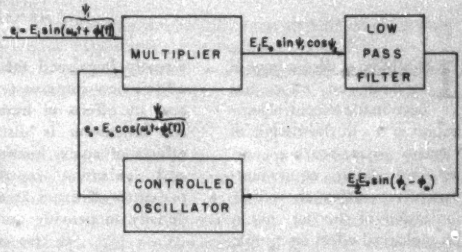

Fig. 1. Simplified block diagram of a closed-loop system for control of an oscillator

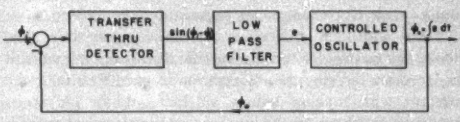

Fig. 2. Phase-equivalent circuit of a closed-loop system for synchronizing an oscillator in phase and frequency with an incoming wave

inspection of the "Bode" diagram of the system, that is, the plot of loop gain magnitude versus frequency on log-log co-ordinates. The equalization may be carried out on a small signal basis in which the phase detector may be represented by a linear transfer function. That the equalization is also effective on the large signal basis has been shown by tests run not only on the actual system but also on the system as synthesized on an analogue computer.

EXPERIMENTAL RESULTS AND CONCLUSIONS

THE phase equivalent circuit shown in Fig. 2 was set up on an analogue computer. Results show that considerable improvement in operation is possible if the system is properly equalized. Furthermore stability can be maintained even with increased loop gain. An increase of 10 to 1 in loop gain and proper equalization reduced the synchronizing time by a factor of 10 and extended the pull-in range by a factor of 2. This was by no means the limiting case. The designer could choose to further increase the loop gain so as to decrease the pull-in time and increase the pull-in range, or he could choose to increase the time constant of the system to enhance its insensitivity to noise and to cause it to maintain lock-in during somewhat longer fades.

Further tests were made using the actual system to check the analysis. The correlation of the results from the actual system and the system as synthesized on the computer were good.

Air Ionization as an Environment Factor

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Greatly improved measuring techniques have added new impetus to the study of ionized air and its effect on human health and comfort. Air ionization is discussed in terms of the effects of space heating and room occupancy and ionization control. Experimental work presently directed at accurately measuring ion density to provide automatic means of control is also considered.

IN VIEW of the findings of research, an effort has been made to control ionization of air in the design of electric space-heating and air-conditioning equipment. Extensive studies show that ionization of the air has a physiological effect on people breathing the air, and it is reasoned that air conditioning should not inadvertently change any property of fresh outdoor air if a change can reasonably be avoided.

Until additional biological experiments can show how to use ion control for relief of specific diseases or ailments, it is necessary in using the information learned thus far to be content with making indoor air like outdoor air at its best, before attempting to improve on the electrical properties of fresh air.

Interest in this work originated from the knowledge that electric heaters produce ions. With well-established proof that ionization is an environment factor affecting well-being and comfort, the next step was to apply this knowledge in the design of an ion-controlled electric heater.

When air conditioning is spoken of it is usually in terms of circulating air combined with heating or cooling, filtering, humidifying, and dehumidifying. These are the basic requirements for comfort in control of the atmosphere in which we live. In spite of the increased interest in research activity which has taken place since World War II, there still remains the unsolved question of the importance of air ionization as an environment factor.

IONS AND HEALTH

THIS subject of ionized air as affecting human health and comfort has been discussed for over 50 years. It received considerable attention during the late 20's and 30's[1] and is now being actively studied again with the aid of greatly improved measuring techniques. Research work is diligently being pursued at Stanford University in both the electrical engineering and chemistry departments, at the University of San Francisco in the biology department, and at the University of Arizona.

F. W. Hutchinson, mechanical engineer at the University of California, summarized progress in this field near the end of World War II.[2] In brief, he noted that the ion content of air varies with many factors and there is some evidence for believing that ionization is either partly responsible for, or in some indirect way related to, the feeling of freshness in air.

He noted, too, that present air-conditioning methods affect the ion content of air appreciably and that heating engineers must understand how to control ions as ions might affect health and comfort.

Air-conditioning engineers are concerned with the methods of removing pollutants from the air with due regard to particle size. In addition to particulate matter, however, there is the influence of electric charges on particles and molecules of gas making up the atmosphere. Uncharged particles below one-tenth micron in size are one thing but charged particles behave differently. What of them, and what of ions themselves? These charged particles and molecule complexes are commonly referred to as ions and may be classified into ion groups.

Ion Groups:

There are three general groups of atmospheric ions: (1) Small ions are molecular complexes of a dozen or so gas molecules associated with one electrically charged molecule. (2) Intermediate ions generally exist in quantity near cities and areas of air pollution. They are submicroscopic particles believed to be formed where sulphuric acid particles from smokes are present or from hydrated ions.[3] (3) Large ions consist of clusters of small ions surrounding condensation nuclei or single charged particles of smoke. They are most common in urban areas or indoors where contaminates are present. Large ions are not particularly important as distinguished from uncharged particles because these particles can be filtered by mechanical means and the relative effect of one or two electric charges on a particle of such great mass is negligible.

At present little is known about the intermediate ions because they are too small to be seen and difficult to isolate from the small ion group. It should be kept in mind that though ions have been grouped in these three size ranges for convenience, there is no clear line of demarkation.

Particles Affecting Health:

One of the most important physical factors in the causation of pulmonary disease is the size of particles, since only those particles below a certain size can reach the finer passages and air sacs of the lungs and start those changes leading to disease.[4] Some of the particles that eventually

Full text of paper 54-225, "Air Ionization as an Environment Factor," recommended by the AIEE Committee on Domestic and Commercial Applications and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21-25, 1954. Published in AIEE *Applications and Industry*, September 1954, pp. 161-65.

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reach the ultimate pulmonary tissue are deposited. It is known that this deposition within the lungs is selective and only particles below 5 microns are able to penetrate to the lungs.[5] It has been observed that particles 1 micron in size most readily reach the lungs. Thirty-five per cent of the 0.1-micron-size particles are known to be retained. (These, if charged, would be classified as large ions.) Of particles below 0.1 micron about 25 per cent are retained. It is not safe to say that particles below 0.1 micron are biologically unimportant, as many engineers are prone to do. The behavior of particles of this small size (when electrically charged) is known to be different from their behavior when electrically neutral, owing to their small mass in proportion to the force of the electric charge on them.

Ions Affecting Health:

It is well known that particles deposited in the lungs affect health. Another question, still unsolved, is what effect, if any, does an electric space charge in a room have on a person's feeling of well-being? In order to answer this question something must be known about the number of ions of each size found in free air, in closed rooms with and without air conditioning, and the magnitude of space charge that can be formed in a given room.

A. Biological Aspects of Ions:

Historically, considerable effort was made to evaluate clinically the biological and physiological significance of atmospheric ions. Though these tests appeared to show a trend or pattern that was consistent, the results never stood up under a careful statistical evaluation nor could the reports be duplicated at will. The principal difficulty appears to have been in trying to establish the facts by clinical methods in which control of the patients was inadequate to rule out other variables.

Biological studies with animals appear now to be the only practical solution for establishing the facts regarding the influence of ions on basic body functions. Once this has been accomplished, a carefully controlled clinical test can then be run on some simple indicator such as the mucous membrane of the nose, throat, and trachea.

Early investigators finding it difficult to create relatively high ion densities free from ozone and oxides of nitrogen resorted to the use of magnesium oxide particles to reduce the mobilities of the ions and thereby permit higher concentrations. It was assumed the magnesium oxide was nontoxic and the particle size too small to be biologically harmful. It appears now that both assumptions were wrong to an extent that forces us to discard the results thus obtained.

If ions in the atmosphere are indeed important to consider in the design of air-conditioning equipment, then it follows that the ions used for test, large or small, positive or negative, should be in quantities that might normally be found while working with such equipment.

B. Experiments With Animals:

Biological experiments are still going on, but certain facts have been established:

1. Atmospheric ions at the relatively low densities that occur in free air do have a biological effect. This effect generally is so subtle on normal, healthy animals that it is necessary to use extremely sensitive indicators in order to establish the changes.

2. A sudden reversal in polarity of ionization momentarily disturbs the normal development and growth of animals.

3. Fundamental changes are mediated through the adrenal glands indicating possible therapeutic usefulness of ionized air.

4. Positive ions produce the most striking changes that are shown to be statistically significant.

5. Length of exposure is an important factor as animals adapt themselves to a given environment.

IONIZATION OF THE AIR

Ionization of air as an environment factor refers to the natural ion density as found in free air near the earth's surface the world over. This density varies from less than 200 ions per cubic centimeter to over 1,000 ions per cubic centimeter. The positive small ions generally exceed the negative small ions by a slight amount in the ratio of 5:4.[6] This difference in number of ions results in a space charge in which the air of the room may be described as being at a potential different from that of the walls of the room. See Fig. 1.

The small-ion density is observed to decrease at times of high relative humidity or air pollution but this does not account for all of the variations observed. In a series of tests conducted at the University of Tennessee Engineering Experiment Station in Knoxville,* a change in humidity had little effect on the ion density of free air. There appears to be a 12-hour cycle, but changes in temperature and humidity are not the primary cause.

Effects of Space Heating and Room Occupancy. Ion density in rooms varies according to occupancy, heat source, air contamination, and circulation. Professor Yaglou found that in unoccupied rooms the ion content of the air was not very different from that out of doors, but in occupied rooms the ion content showed a decrease depending upon the size of the room and the number of occupants.[7] Experiments conducted by the Wesix Electric Heater Company have

* Sherwood King and C. L. Carter, University of Tennessee Engineering Experiment Station, 1955.

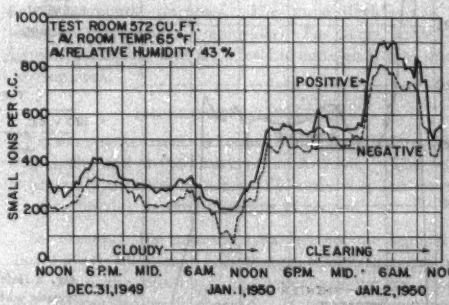


Fig. 1. Typical small-ion density curves for room ventilated through an open window, Pacific Heights, San Francisco

established the change in ion density that results from use of a heater employing high-temperature metal, 1,000 F and higher. Experiments by Professor Yaglou, confirmed by others, have established the changes that result from passing air through long ducts, and measurements reported show that the air is not freed from ions even after it passes through filters and is washed with water.[8]

The magnitude of the charge resulting from heating and transporting air may be considerable. In one experiment the positive ion density in a large room was raised from 800 ions per cubic centimeter to over 17,000, and the negative ions were reduced from 200 ions per cubic centimeter to almost zero by an industrial fan-type electric heater. See Fig. 2. Most of the positive ions were produced by the elements of the electric heater operating at a temperature of about 1,000 F. A few can be attributed to the presence of 19 students in the classroom. Initially, the negative ions disappeared completely, but after about 2 hours' operation there was again a small concentration. This is believed to be related to the lack of physical activity of the students and the consequent light breathing and small absorption of negative ions after 2 or 3 hours.

Similar changes, though less prominent, have been observed in rooms supplied by air from ventilation systems. Change in the ion content of air supplied through ducts results from the selective absorption of negative ions because these ions have a higher mobility on the average than do positive ions and are therefore lost to the walls of the duct by diffusion at a higher rate.

Aiding this natural tendency for negative ions to be separated out of air passing through ducts is the natural absorption of negative ions by metal surfaces. H. S. W. Massey states that in an encounter with a metal, a negative ion can lose its electron easily to the metal, provided the work function of the metal is greater than the detachment energy of the ion.[9] In this case there is an unoccupied level for the electron in the metal with energy equal to that of the level which it occupies in the ion, and the transfer will be a resonance phenomenon. Since most metal surfaces have work functions greater than the electron affinity of even fluorine it is clear that such surfaces will play a very important role in the destruction of negative ions.

On the other hand, negative ions are relatively difficult to produce, particularly in connection with heating systems,[10] and it is seldom that the negative ion density of a room will exceed 1,500 ions per cubic centimeter either naturally or by artificial means.

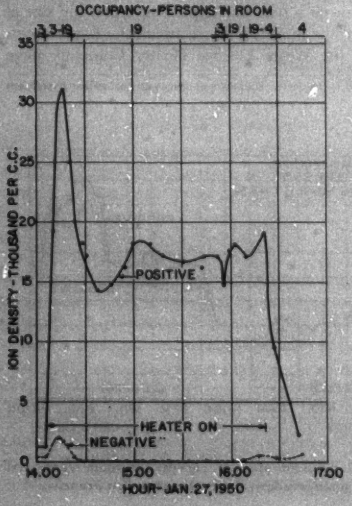
There may be one condition in which a net negative ion density is produced by air conditioning in a conventional manner. This is when a water wash system is used and the fine spray causes the formation of many large negative ions by the well-known Lenard effect.[11] As a general rule, positive ions far exceed the negative ions in occupied air-conditioned rooms unless special precautions are taken to avoid it.

Control of Ionization. Control of atmospheric ions can be provided with any air-conditioning equipment. Unfortunately, it cannot be done by filtering alone. Some ion generation must be provided to introduce ions into the air.

A. The Ion-Controlled Electric Heater. The conventional electric heater using an exposed nickel-chromium element generates a preponderance of positive ions. These ions repel each other and disperse through the room. A simple suggestion to overcome this difficulty would be to design the heater with a maximum metal temperature well below the ion generation point of approximately 1,000 F.

This suggestion, however, would eliminate one of the principal advantages of an electric heater: air purification through incineration. Bacteria, mold spores, and organic dust particles such as wool, cotton, etc., are destroyed when circulated through the conventional radiant-convection type of electric heater in which the air speed is approximately 180 feet per minute. The temperature of the element wire in these heaters varies from 1,100 to 1,500 F. The temperature of the ceramic supporting chimney for the coil will run 900 to 1,200 F. This is sufficient to incinerate all bacteria and organic material that go through the chimney and most of that which passes within 1 inch of the coil itself.

At the Naval Biological Laboratories, located at the Naval Supply Center in Oakland, incineration is used as the only sure means of destroying dangerous bacteria being handled in the Laboratories for experimental pur-



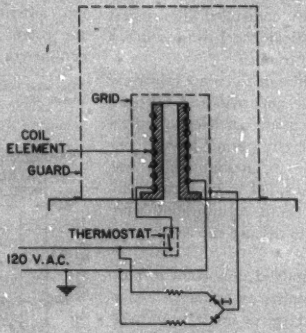


Fig. 2 (left). Room ion density characteristic with industrial-type 9-kw electric fan heater. Fig. 3 (above). Ion-controlled electric heater with charged grid close to element wire

poses. Various filters and aerosols were tried but the simple use of incineration was found to be by far the most effective.

The thermal force that causes precipitation on colder surfaces tends to drive particles away from a red-hot heater element unless special precautions are taken. This force is equally disposed on particles passing through the cylindrical chimney, however, and therefore is ineffective in preventing incineration of particles that enter the chimney. Near the outside of the chimney considerable improvement can be achieved by providing an electrostatic field to counter the thermal gradient directing particles away from the element.

Such an electrostatic field can also be used to control the ions coming from the heating element. In both cases the field from a negatively charged screen can be used, for it is desired to collect positive ions and attract positively charged particles. The structure in its simplest form consists of a grid 1/8-inch mesh, placed over the heating element and spaced approximately 1/8 inch from the element coil. See Fig. 3. A negative potential is impressed on this grid to attract positive small ions projected from the heated coil. This negative charge will also attract small charged particles. The proximity of the grid to the coil provides sufficient heat on the grid to cause incineration at that point.

It has been discovered that an unfiltered rectified voltage applied to the grid will project the few available negative ions into the airstream where they will be carried into the room. The phenomenon is not unlike that which takes place in the standard radio tube with filament, grid, and plate. During the moment that there is no potential on the grid, negative ions flow through the openings in the grid. When the negative charge again comes on the grid it forces the negative ions farther away from the grid and into the airstream. Thus, a negative space charge can be created in a room. This is useful in overcoming the tendency of a positive space charge to form when the room is occupied, particularly by cigarette smokers. Fig. 4 illustrates the results achieved using this method of ion control on a radiant convection electric heater. The addition of the grid adds very little to the cost of the heater and effectively improves air purification and ion control.

B. Disadvantages of High-Voltage and Ultraviolet Ion Sources. To provide desired ion concentrations, various ion sources are possible. The use of a thermionic source, as the hot wire of an electric heater, has been mentioned. High-voltage discharges and X-ray and ultraviolet radiation are also ion sources. The latter are limited because of the danger of producing ozone and nitrogen oxides at the energy levels required to produce ions.

In areas of air pollution there are already abnormal amounts of ozone (as found in the Los Angeles area by the Stanford Research Institute). This excess of ozone is responsible for much throat and nasal irritation and no additional ozone as a result of air conditioning can be tolerated. In fact, it can be argued that the present excess should be removed. But electrostatic precipitators produce ozone when a flashover occurs, and such flashovers are frequent when the plates need cleaning. Ultraviolet lamps produce ozone as well as ions. Both devices, in the form that they are now used in ventilation systems, provide an excess of positive ions. There is a twofold problem here of

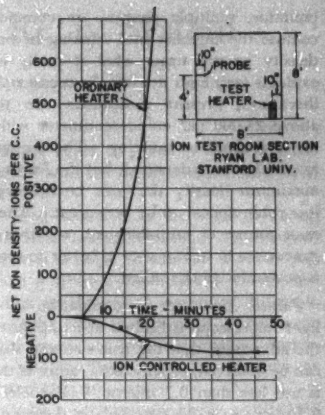


Fig. 4. Comparison of room ion density characteristic of an ordinary electric heater versus an ion-controlled electric heater

controlling both ions and ozone. So much difficulty has been experienced with high-voltage and ultraviolet sources of ions, because of ozone, that other ion sources have thus far been preferable.

C. Radioactive Sources. Recent experiments have been conducted following this general conclusion. Small ions were generated using an alpha emitter, Polonium 210, as a source. In this way there was no alteration of the temperature, the relative humidity, the air velocity, nor any possibility of producing ozone, oxides of nitrogen, or hydrogen peroxide. The polonium foil material for this work is a carefully prepared commercial product entirely free from migration and possible radioactive contamination.[13]

The ions formed by polonium are initially small ions with high mobilities. Over a period of time some may attach themselves to particulate matter present and become intermediate-size ions and possibly a few large ions. Many of them will be lost before this takes place by absorption on nearby objects. Thus, a constant supply of ions must be produced in order to maintain a specified density.

Convenient ion generators have been developed so that there is no longer any problem in ionizing an animal cage for experimental purposes. The same devices can be used in the home or clinically. For large forced-air systems a different unit is preferable and this is now under development.

EXPERIMENTAL STUDIES

Experimental work is continuing at Stanford University and at the University of Arizona. This work is presently directed at accurately measuring ion density so as to provide automatic means of control.

Ion Counters. Ion counters measure, not the number of ions, but the number of unit charges of electricity, so that their use for the counting of ions depends on the assumption that the ions are singly charged. It is only under unusual circumstances that multiple charged ions exist in free air.[13] However, in a device such as an electrostatic pre-

cipitator, multiple charges are common and sometimes confuse the engineer into thinking he has obtained an ion density several times what it really is. This probably explains very high densities as occasionally reported in the literature. Present indications are that ion densities above 25,000 per cubic centimeter will not occur in the air of a room or building. The reasons for this are not as yet clearly understood, but the forces acting to limit the maximum density that can be achieved to a relatively low value appear to be very great. The use of Radium D as a source of unipolar ions, together with placing ion generators in such a way as better to spread unipolar ions, is presently being studied.

Particle Size. For determination of particle size, the light microscope is limited in its application. It possesses the advantage that the true size and shape of the particle can be observed, provided the radius of the primary particle is not less than 0.3 micron.[14] Particles between 0.1 and 0.3 micron can be detected by polarization.[15] Below this size the microscope cannot be used at all because smaller particles scatter light to an extent which depends on the inverse fourth power of the wavelength of the light and on the sixth power of the radius of the scattering particle.

The electron microscope is not of much help because particles are not observed in the dispersed state and may be altered during or after sampling. This is especially true of fog droplets which are evaporated and distorted by the energy in the electron beam.[16] The electron beam is an ionizing source itself and cannot be used to study the behavior of charged particles.

Some work has been done by tagging very small particles with radioactive material, or, by various means, making them radioactive. Much of this work is classified and the result can only be guessed at. In the San Francisco Bay Area two major efforts are being made using this method—one at the Navy's Bacteriology Laboratory under Dr. A. P. Krueger and the other at the United States Naval Research and Development Laboratories at Hunters Point under the direction of Dr. E. R. Tompkins and Lieutenant Commander Royce Skow. At the New Mexico School of Mines some work has been done on "naturally" radioactive particles in air. It was learned that the observation of a major size group at 0.018 micron agrees well with previous knowledge of the dominance of intermediate atmospheric ions having mobility of about 0.02 cm per second per volt per cm.[17] An indication of the presence of particles down to about 0.002 micron was detected using this method.

The importance of the difficulty of observation has not been stressed enough, because too often the air-conditioning engineer has gone on the assumption that there are no particles of importance below 0.1 micron simply because he cannot find them. The tools to observe particles suspended in air with diameters below 0.1 micron are still limited, but such particles are present in considerable number. It is these particles which when ionized are believed to be of biological importance in relation to health and comfort.

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Navy Experiment Station Marks 50th Anniversary

This year marks the 50th anniversary of the U. S. Naval Engineering Experiment Station at Annapolis, Md., the Navy's oldest laboratory specializing in the solution of shipboard machinery problems. Funds for its establishment were authorized by Congress in 1903; the first director reported for duty on July 2, 1904.

The original investment was $400,000: the mission "to test and determine the suitablity of certain steam machinery for use in naval vessels." With a present plant value of $12 million, the station now includes the testing and development of new types of power plants and propulsion systems, the quieting of vessels to reduce danger of detection, and continuous improvement of machinery, equipment, materials, fuels, and lubricants.

Original plans called for construction of the station on the grounds of the U. S. Naval Academy, but due to lack of space for future expansion there it was built on its present site across the Severn River. It now occupies 59 acres with seven major laboratories as well as the supporting shops and facilities.

One Approach to a Video SHF Relay System

R. H. COE F. F. McCLATCHIE

THIS ARTICLE sets forth the requirements to be met by an ideal superhigh-frequency (shf) relay system for a common carrier communications company's temporary use in Southern California, briefly enumerates the basic considerations prior to the decision to procure such a system, and describes the solutions to some problems encountered during the procurement process.

The three primary requirements to be met by a temporary service shf relay system are portability, frequency of operation, and r-f power. Considering each requirement individually:

Normally two men are available at a relay point during the installation and circuit line-up operation. A significant saving in labor expense is realized if these men can transport the relay system to the operation point without assistance, therefore a weight limitation of approximately 50 pounds per component has been adopted as a design objective for the ideal system.

A portion of the frequency spectrum around 6,000 mc has been allocated for common carrier use. It therefore is taken as a design objective that the ideal relay system will utilize frequencies in the 6,000-mc band.

Terrain features in Southern California provide many natural ideal microwave relay locations. Frequently it is possible to obtain line-of-sight paths in excess of 50 miles. To provide high-quality microwave channels over paths of this magnitude, with reasonable fading margin, r-f power in the order of 1 watt should be available.

A study of the economic aspects of the ideal system versus available microwave relay systems would, in part, consider total length of path per customer order, simultaneous service demand, relay systems required to meet customer requirements, and plant investment necessary to meet customer requirements.

It was determined from considerations similar to the foregoing that the ideal system would be a desirable facility for use in the company's operations and steps were taken to procure such a system. It was found that none was available in sufficient quantities to meet the anticipated demand but that existing Radio Corporation of America (RCA), *TRR/TTR* systems could be modified to meet the requirements of the ideal system.

An integral variable wavemeter accessible to the operator during system use and illuminated for night operation has been incorporated in the transmitter and receiver unit design. Variable wavemeters provided at the transmitter and receiver permit the rapid interchange of one maintenance spare equipment with any other system in the event of relay link failure.

The wavemeter being accessible to the operator during system use permits the following additional applications: At the transmitter it is possible to monitor klystron frequency drift, execute a klystron linearity adjustment, test the klystron deviation sensitivity, and monitor the video signal off the air; at the receiver location it is possible to measure transmitter frequency, rapidly realign system after replacing the local oscillator tube, and identify the frequency of any interfering shf signal.

A video input switching arrangement has been provided at the transmitter which selects one of two terminated customer feeds, an external test signal input, or an internally generatd 60-cycle test level.

An interlock arrangement for personnel protection has been inserted in the system power supply leads. It is recognized that maintenance personnel must disable this protection arrangement when working on these units. The interlock disabling operation creates the possibility that systems might be returned to service with the interlock system electrically by-passed. A positive safeguard against this dangerous possible error is provided in a mechanical interlock by-pass that simultaneously prevents the positioning of the unit for service when personnel interlock protection is disabled.

The susceptibility of the receiver to extraneous intermediate amplifier interference has been reduced by shielding the receiver unit, double shielding control and camera cables, and filtering all exposed leads. The combined result of these measures is better than 60-db suppression of a test interfering signal at 127.7 mc.

A differential phase and differential gain equalizer applique has been designed for use when National Television System Committee color signals are transmitted over the system. In this connection three separate 2-link services have been established which measured zero differential phase and zero differential gain when properly equalized.

The attempt to approach an ideal shf relay system through the modification of an RCA *TTR/TRR* system has led to the following conclusions.

1. It is possible to retain the desirable features of a *TTR/TRR* relay system when it is modified to meet the special needs of a communications company.

2. Significant savings in maintenance costs, operation costs, and plant investment are to be derived from the use of higher r-f power output.

3. Short-range operations (up to 40 miles) are simplified through the reduction in number of relay links required to give service.

4. Long facilities may be established which could not be attempted with equipment previously available.

Digest of paper 54-239, "One Approach to a Video SHF Relay System," recommended by the AIEE Committee on Radio Communications Systems and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21-25, 1954. Published in AIEE *Communication and Electronics*, September 1954, pp. 323–9.

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The authors are indebted to the following for information furnished in connection with the preparation of this paper: F. W. Bailey of Lambda Pacific Engineering for data on waveguide components; J. H. Clark of Pacific Telephone and Telegraph Company for data on color transmission; E. M. Hitchcock of Pacific Telephone and Telegraph Company for data on interference suppression.

Planning the Swedish Extra-High-Voltage System

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BECAUSE OF THE availability of ample water power resources combined with a lack of cheap fuels the electric power supply in Sweden is based almost exclusively on water power. Of the water power resources suitable for exploitation which are now assessed at 80,000 million kwhr per annum, 15 per cent is located in the densely populated southern part of the country. The remainder is found in the northern half inhabited by only 15 per cent of population. The resources in the North are now being developed, and 75 per cent of the power produced is transmitted to the South. In 1953 1,540 megawatts (mw) were transmitted and it is anticipated that by the year 1960 the maximum capacity will be increased to 3,300 mw. The average transmission distance is about 300 miles.

An investigation relating to the transmission costs resulting from the employment of different transmission systems was undertaken in 1946 and showed that a system with a maximum service voltage of 400 kv would prove the most economical. Two years' experience now have been obtained with operation at 400 kv and the resulting costs therefore are better known. Furthermore, autotransformers, series capacitors, and a lower insulation level have been introduced. From a new investigation it has been found that for the Swedish main transmission system 400 kv is approximately 40 per cent cheaper than 230 kv under equivalent conditions.

The stability conditions play a very important part. In principle, each section of the installation is designed in such a way that the limit costs for an increased transmitting capacity will be the same throughout the whole system. This has led to the selection of low reactances for the generators and transformers in the power stations, the employment of quick-acting voltage regulators for the generators, high-speed circuit breakers and relay protection, high-speed reclosing on important transmission lines, instantaneous disconnection of reactors on line faults, the use of autoconnected system transformers, the installation of synchronous condensers in the receiving stations, and series capacitors in the transmission lines among other things.

Series capacitors have proved to be one of the cheapest methods of improving the stability and thus increasing the loading capacity. With transient stability for every fault location 700 to 800 mw can be transmitted per 400-kv single-circuit line with duplex conductors. The very high line capacities with the maximum degrees of compensation justify the use of a heavier cross section than the 2 by 1,170,000 circular mils per phase employed hitherto. It has been found economical to allow for the installation of a third conductor per phase of the same heavy section in the future. The triplex line thus obtained will have a transmitting capacity of 900 mw at the receiving end with 60 per cent compensation of the line reactance.

The demand for transmitted power is increasing continuously. In order to determine the optimum time for installing new 400-kv lines a comparison is made for the years concerned of the total annual costs for the main transmission system with and without the new line, due consideration also being given to operating reliability.

The individual power stations are relatively small, only exceeding 100 to 200 mw in exceptional cases, and they are located at considerable distances apart. The most favorable economy for transmission to the south is achieved when the power from a given district is allowed to accumulate in a local system for 230 or 138 kv and is then fed into the 400-kv system through autotransformers. This generally takes place in one of the district's largest power stations in which the generators are connected to the transformer's delta-connected tertiary winding.

The 400-kv transformers usually consist of three single-phase units with a fourth spare unit. In the production district replacement is effected by means of isolating switches during a short interruption. At the receiving end the exchange is carried out with the help of circuit breakers and isolating switches. Regulating transformers which are normally connected to the 400-kv neutral point are employed in the receiving stations but not in the power stations. The insulation level is 1,500 kv.

The power lines are constructed as single-circuit lines. Intermediate switching stations are not employed. Three-pole high-speed reclosing is adopted when a line is connected in parallel with a network. Single-pole high-speed reclosing will be introduced for line sections shorter than 150 miles. Field tests have shown that the secondary arc cannot be extinguished on longer lines. The first 400-kv series capacitor was placed in service in January 1954. Two further similar installations will be started up during 1954 and 1955.

Owing to the difficulties encountered in obtaining a low tower resistance it is estimated that the lightning faults frequency will amount to 0.25 fault per 100 miles and year on the average. Hitherto, six lightning faults have been recorded, five of which were single phase. None of these faults has caused breakdown in the stability.

A constant attempt is being made to standardize the voltages below 400 kv. Attention is being primarily directed to the 400-, 138-, 40-, 10-kv voltage chain. In networks operating at 138 kv and higher voltages the neutral point is directly grounded. The short-circuit power is increasing. New circuit breakers, transformers, and switchgear are designed for 18,000,000 kva at 400 kv, 10,000,000 kva at 230 kv, and 7,500,000 kva at 138 kv.

Digest of paper 54-216, "The Planning of the Swedish Extra-High-Voltage System," recommended by the AIEE Committee on System Engineering and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1954.

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Field Equivalence Theorems and Their Circuit Analogues

R. F. HARRINGTON

Common misconceptions both in the theory and application of the field equivalence theorems have occurred due to a misunderstanding of the role of "impressed currents" as well as the lack of a sufficiently clear and elementary exposition of the theorems. Both are discussed here together with terminating currents and circuit analogues.

THE equivalence theorems of Schelkunoff[1] have been gaining widespread acceptance in recent years. However, there are prevalent misconceptions both in the theory and in the application of the theorems. These arise out of a misunderstanding of the role played by "impressed currents," and from the lack of a sufficiently comprehensive and elementary exposition of the theorems themselves. When properly understood, they are powerful analytical tools, equivalent to the use of Green's functions. In fact, they are related to the latter by reciprocity. Professor V. H. Rumsey, in his lectures at Ohio State University, has done much towards interpreting the equivalence theorems on a rigorous basis.

The following development is carried out in terms of sinors (also called phasors),[2] although an analogous development in terms of the time-varying vectors is also possible. This, of course, restricts it to steady-state, harmonic time-varying fields. Thus, a scalar quantity is interpreted according to

$$v = \sqrt{2}|V| \sin(\omega t + \alpha) = Im(\sqrt{2}\, V e^{j\omega t}) \tag{1}$$

where v is the time-varying quantity and $V = |V|e^{j\alpha}$ is the sinor (complex) quantity. For vectors, there is the extended concept

$$\mathcal{E} = Im(\sqrt{2}\, \mathbf{E} e^{j\omega t}) \tag{2}$$

where $\mathcal{E}$ is the time-varying vector and $\mathbf{E}$ is the sinor (complex) vector. Equation 2 should be interpreted to mean that the components of $\mathcal{E}$ are related to the components of $\mathbf{E}$ according to equation 1.

The electromagnetic field is defined in terms of the two vectors, the electric intensity, $\mathcal{E}$, and the magnetic intensity, $\mathcal{H}$. The properties of media are specified in terms of σ, the conductivity; ϵ, the capacitivity (permittivity); and μ, the inductivity (permeability). Only linear media are considered, and all matter is taken to be stationary with respect to an observer. It is assumed that Maxwell's equations hold for all macroscopic electromagnetic phenomena in source-free regions. (The term "source" refers to an energy source.) These equations, in terms of sinors, are

$$\nabla \times \mathbf{E} = -j\omega\mu \mathbf{H} \tag{3}$$

$$\nabla \times \mathbf{H} = (j\omega\epsilon + \sigma)\mathbf{E} \tag{4}$$

where $\mathbf{E}$ and $\mathbf{H}$ are the sinors of $\mathcal{E}$ and $\mathcal{H}$. Equations 3 and 4 do not hold for regions internal to generators. The term $j\omega\mu\mathbf{H}$ is the sinor of the magnetic displacement current density, $j\omega\epsilon\mathbf{E}$ is the sinor of the electric displacement current density, and $\sigma\mathbf{E}$ is the sinor of the conduction current density. These are all caused by the action of sources, and are called induced currents. Only the conduction current may be visualized as the flow of charged particles.

IMPRESSED CURRENTS

STRICTLY SPEAKING, there must be an energy source for any steady-state a-c field, since some dissipation and radiation of power is always present. (A mathematical exception to this statement is made in the case of idealized resonant cavities.) Thus a method should be devised whereby the effect of such sources may be taken into account. This is done in the following manner. First, source terms are introduced into Maxwell's equations. The mathematical properties of such terms are then investigated. Next, a method of expressing the characteristics of actual sources in terms of these mathematical sources is devised. This is analogous to the treatment of sources in circuit theory. For that case, ideal voltage and current sources are postulated, and then it is ascertained how actual sources can be represented in terms of these ideal sources. In field theory, the ideal sources are called impressed currents.

Consider Maxwell's equations rewritten so that each contains a source term. These are

$$\nabla \times \mathbf{E} = -j\omega\mu \mathbf{H} - \mathbf{m} \tag{5}$$

$$\nabla \times \mathbf{H} = (j\omega\epsilon + \sigma)\mathbf{E} + \mathbf{j} \tag{6}$$

The term $\mathbf{j}$ is the sinor of the impressed electric current density, and $\mathbf{m}$ is the sinor of the impressed magnetic current density. There is no direct physical interpretation for either impressed electric or impressed magnetic currents. However, a better intuitive feeling for impressed electric currents has been acquired than for their magnetic counterpart. This is undoubtedly due to the physical existence of electric charges, and to the close mathematical relationship between conduction currents and impressed currents. The postulation of impressed magnetic currents in no way implies the physical existence of magnetic

A special article recommended for publication by the AIEE Subcommittee on Applied Mathematics.

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charges and currents in nature. They are employed solely as a mathematical convenience, in a manner similar to that for the afore-mentioned voltage and current sources of circuit analysis.

The integral form of Maxwell's equations, generalized to include impressed currents, can be obtained by integrating equations 5 and 6 over a surface S encircled by a contour C. Applying Stoke's theorem to the result gives

$$\oint_C \mathbf{E} \cdot d\mathbf{l} = -\int\int_S j\omega\mu \mathbf{H} \cdot d\mathbf{s} - \int\int_S \mathbf{m} \cdot d\mathbf{s} = -K^i \tag{7}$$

$$\oint_C \mathbf{H} \cdot d\mathbf{l} = \int\int_S (j\omega\epsilon + \sigma)\mathbf{E} \cdot d\mathbf{s} + \int\int_S \mathbf{j} \cdot d\mathbf{s} = I^i \tag{8}$$

where K^i is the sinor of the total magnetic current through the surface S, and I^i is the sinor of the total electric current through the surface S.

Of major importance in the theory which follows are the properties of thin sheets of impressed currents. Let $\mathbf{J}$ denote the sinor of an impressed electric current surface density, and $\mathbf{M}$ denote the sinor of an impressed magnetic current surface density. Consider a surface S upon which some distribution of electric and magnetic currents is impressed. This is shown in Fig. 1. Denote the region on one side of the current sheet region *1*, and the other side region *2*, and let a superscript on a symbol signify the region in which it is considered. The unit normal to the surface, pointing into region *1*, is denoted by $\mathbf{n}$. The parameters of the media in both regions, σ, ϵ, μ, are considered to be finite, and there is not necessarily any discontinuity in media at the surface S. Applying equations 7 and 8 to a rectangular path, of infinitesimal dimensions, enclosing a portion of the current sheet, the boundary conditions satisfied by the field at such a current sheet can be obtained. The results are

$$\mathbf{n} \times (\mathbf{H}^1 - \mathbf{H}^2) = \mathbf{J} \tag{9}$$

$$(\mathbf{E}^1 - \mathbf{E}^2) \times \mathbf{n} = \mathbf{M} \tag{10}$$

The behavior of the normal components of the field is not an independent relation. They are related to the tangential components through equations 5 and 6. Thus, a sheet of impressed electric current is accompanied by a discontinuity in the tangential component of the magnetic intensity, equal in magnitude to the current density, and at right angles to it. There is no discontinuity in the tangential component of the electric intensity across an electric current sheet. A sheet of impressed magnetic current is accompanied by a discontinuity in the tangential component of the electric intensity, equal in magnitude to the current density, and at right angles to it. There is no discontinuity in the tangential component of the magnetic intensity across a magnetic current sheet.

Now consider the concept of perfect conductors. The use of a perfect electric conductor as an approximation to a good conductor is widespread. It is defined as a material for which the tangential component of the electric intensity is zero at its surface. Such conductors will be used as a boundary surface. This could be considered mathematically as a "boundary condition." In addition, it is sometimes advantageous to use the concept of a perfect magnetic conductor as a boundary surface. This is defined as a material for which the tangential component of the magnetic intensity is zero at its surface. Schelkunoff calls such surfaces "sheets of infinite impedance."[3] The postulation of magnetic conductors in no way implies the physical existence of them, although surfaces can sometimes be obtained which act like a magnetic conductor in practice. They are used merely for mathematical convenience. The short circuit and open circuit of circuit analysis are analogous to the perfect electric conductor and perfect magnetic conductor of field theory, respectively.

The usefulness of perfect conductors for the present purposes lies in the following property. An electric current "impressed" on the surface of a perfect electric conductor (or an infinitesimal distance from it) produces no field. This statement can be proved by means of the rec-

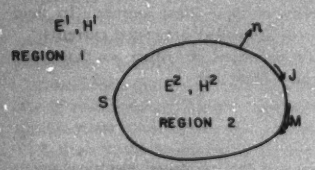
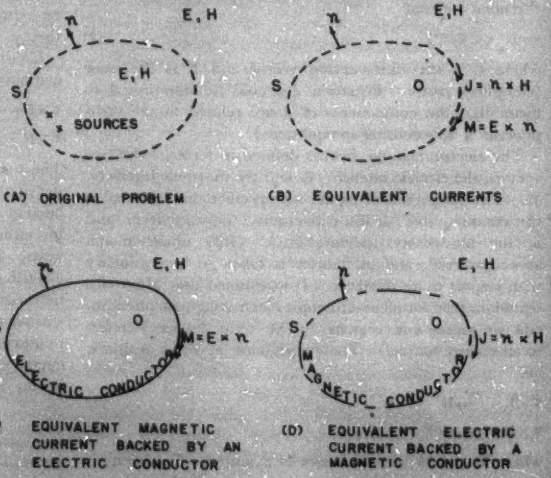


Fig. 1 (above). Impressed electric and magnetic currents over a surface. Fig. 2 (right). All of these configurations produce the same field external to the surface S



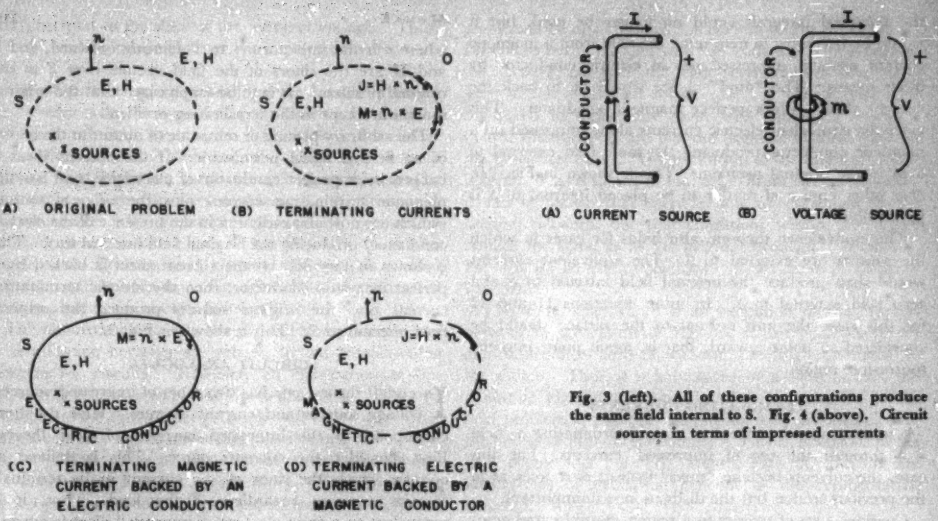


Fig. 3 (left). All of these configurations produce the same field internal to S. Fig. 4 (above). Circuit sources in terms of impressed currents

iprocity theorem for impressed currents.[4] The tangential component of the electric intensity at the surface of a perfect electric conductor, due to an impressed current element a distance from it, is zero. Therefore, by reciprocity, an element of impressed current along the surface of the conductor will produce no component of electric intensity along the axis of the former current element. Since the location and orientation of the former current element are arbitrary, the original statement follows. A corresponding property for impressed magnetic currents can be proved in a similar manner. Thus, a magnetic current impressed on the surface of a perfect magnetic conductor (or an infinitesimal distance from it) would produce no field.

EQUIVALENCE THEOREM

THERE ARE many distributions of impressed currents which will produce the same field within a given source-free region. All such currents are said to be equivalent within the specified region. Of even greater importance, distributions of impressed currents can be found which will produce the same field as some complicated source, for example a transmitter plus its antenna.

Consider a set of sources in a region, possibly nonhomogeneous, and surround them by an arbitrary surface S. The field everywhere is denoted by **E,H**. This is shown in Fig. 2*A*. Now consider a second problem as follows: Keep the properties of space (σ, ϵ, μ) the same as in the original problem, but with the sources "switched off," and consider the same surface S. On S are placed impressed currents such that the field external to S will be **E,H**, and the field internal to S will be zero. This is illustrated in Fig. 2*B*. It is certainly a realizable condition, since the field everywhere is a solution to Maxwell's equations. From equations 9 and 10, it follows that the currents impressed on S are given by

$$\mathbf{J}=\mathbf{n}\times\mathbf{H} \tag{11}$$

$$\mathbf{M}=\mathbf{E}\times\mathbf{n} \tag{12}$$

where n is the unit normal to S pointing outward, and **E** and **H** are the sinors of the field vectors over S in the original problem. The impressed currents given by equations 11 and 12 are called the equivalent currents of the original problem. (Other currents can be found which will produce the same field external to S, and a different field internal to S, but the name equivalent currents will be reserved for the ones given previously.)

The fact that the field of the equivalent currents is zero internal to S is of great importance. This permits the removal of any or all matter from within S and its replacement with any matter desired, without affecting the field external to S. Mathematically, this is called the arbitrariness of boundary conditions. For example, S could be considered to enclose a transmitter and antenna in the original problem, with only free space external to S. Then, in the equivalent problem, all matter may be removed from within S and the equivalent currents considered to be radiating into free space everywhere. This would permit the use of the potential integral solution.[4] Another useful choice is to back the current sheet with a perfect electric conductor. As shown in the previous section, the impressed electric currents would then produce no field. Thus, the equivalent magnetic currents alone would be impressed on an electric conductor giving the same field external to S as in the original problem. Fig. 2*C* illustrates this condition. This is equivalent to saying that a knowledge of the tangential component of the electric intensity over a surface enclosing the sources is sufficient to determine the field external to S. Of course,

the potential integrals could no longer be used, but it would be necessary to determine the field from a magnetic current element impressed on an electric conductor by other means. The "dual" choice would be to back the current sheet with a perfect magnetic conductor. This gives the equivalent electric currents alone impressed on a magnetic conductor producing the same field external to S as in the original problem. This is shown in Fig. 2*D*. Any other choice of matter to be placed internal to S is permissible.

The equivalence theorem also holds for cases in which the sources are external to S. The equivalent currents would then produce the original field internal to S and zero field external to S. In using equations 11 and 12 for this case, the unit normal to the surface should be considered to point inward, that is, again point into the source-free region.

TERMINATING CURRENTS

ANOTHER useful concept is that of terminating a field through the use of impressed currents. For this case, the currents become "sinks" instead of sources as in the previous section but the distinction is unimportant.

Consider a set of sources in a region, possibly nonhomogenous, and surround them by an arbitrary surface S. Again, the field everywhere is denoted by $\mathbf{E},\mathbf{H}$. This is shown in Fig. 3*A*. Now a second problem is set up as follows: Keep both the medium and sources the same as in the original problem. Then impressed currents are placed on S such that the field internal to S remains unchanged, but the field external is zero. This is illustrated in Fig. 3*B*. For this to be so, the impressed currents considered alone (with the original sources removed) must evidently radiate zero field internal to S, and $-\mathbf{E}$, $-\mathbf{H}$ external to S. Then it would be expected that these terminating currents were just the negative of the equivalent currents. This can be verified by applying equations 9 and 10 to the surface S. Thus, the terminating currents are given by

$$\mathbf{J}=\mathbf{H}\times\mathbf{n} \tag{13}$$

$$\mathbf{M}=\mathbf{n}\times\mathbf{E} \tag{14}$$

where $\mathbf{n}$ is the unit normal to S pointing outward, and $\mathbf{E}$ and $\mathbf{H}$ are the sinors of the field vectors over S in the original problem. It is to be emphasized that the original sources are kept in the terminating problem.

The arbitrary placing or removing of matter in the region of no field is again permissible. If the current sheet is backed by a perfect conductor of electricity, one has the magnetic terminating current plus the original sources (which are now also radiating in the presence of the electric conductor) producing the original field internal to S. This is shown in Fig. 3*C*. If the current sheet is backed by a perfect magnetic conductor, then the electric terminating current plus the original sources produce the original field internal to S. This is shown in Fig. 3*D*.

CIRCUIT ANALOGUES

IN circuit theory, one has two types of impressed sources, voltage sources and current sources. How do these correspond to the impressed currents of field theory? First, consider the current source. This is defined as one for which the sinor of the current in its terminals remains constant regardless of the load. Thus, it is equivalent to a short element of impressed electric current applied in series with a perfectly conducting wire. This is illustrated in Fig. 4*A*. Since an impressed current is independent of the field, it follows that the current delivered by such a source will be independent of the load. Now consider the voltage source. It is defined as a source for which the sinor of the voltage across its terminals remains constant regardless of the load. Its equivalent in terms of impressed currents would be a loop of impressed magnetic current encircling a perfectly conducting wire. This is shown in Fig. 4*B*. An application of equation 7 to a path coincident with the wire and closing across its terminals will verify this assertion. The magnetic displacement current is assumed negligible, as is usual in circuit theory, giving K as the sinor of the total magnetic current enclosed by the path. Since the electric intensity is zero within the wire, there is only the line integral across the terminals,

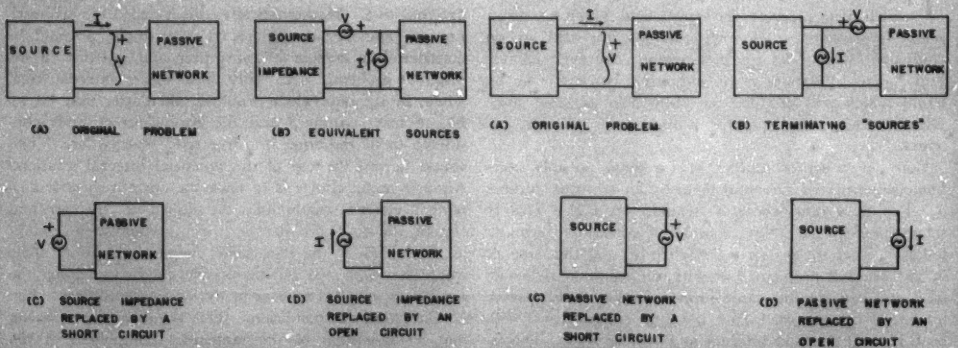


Fig. 5. All of these configurations produce the same excitation of the passive network

Fig. 6. Conditions within the source remain the same for all of these configurations

which is equal to the sinor of the terminal voltage. Thus, $V = K$, and is independent of the current delivered to a load.

Note that the foregoing concept of the sources of circuit theory reduces the theorem of superposition for circuits to an obvious conclusion, as it is in field theory. For linear media (linear circuit elements), the fields and induced currents from impressed currents can be directly added, a consequence of the linearity of Maxwell's equations. A current source, with the impressed currents removed, is an open circuit, as can be seen from Fig. 4*A*. A voltage source, with the impressed currents removed, is a short circuit, as can be seen from Fig. 4*B*. Thus, the statement of superposition for circuits follows directly.[6]

The circuit analogues to the equivalence principle and to terminating currents are related to the compensation theorem for circuits.[7] However, an elaboration of this theorem is necessary to obtain closer analogies. First, the analogue to the equivalence principle will be set up. Consider a complex source connected to a network, as shown in Fig. 5*A*. The sinors of the terminal current and voltage are denoted by I and V, respectively. Now consider a second problem as follows. A current source of excitation I is placed in parallel with the leads from the source to the network and a voltage source of excitation V is placed in series. The excitation of the original source is "switched off," leaving the source impedance connected. This is illustrated in Fig. 5*B*. From an application of circuit theory, it can be shown that there is no excitation of the source impedance from these "equivalent sources," while conditions in the original network remain unchanged. Thus, Fig. 5*B* is the circuit analogue to the field problem of Fig. 2*B*.

Since there is no excitation of the source impedance in the circuit of Fig. 5*B*, it may be replaced by an arbitrary impedance without affecting conditions in the original network. This is analogous to the arbitrary changing of matter in the equivalence theorem (arbitrary boundary conditions). In particular, let the source impedance be replaced by a short circuit, which is analogous to the electric conductor boundary of the field problem. The current source will then be "short-circuited out," that is, all of its current will flow through the short circuit. This can be seen either by considering the voltage source to be as pictured in Fig. 4*B*, or by applying the superposition theorem for circuits to this case. Thus, one has the voltage source alone exciting the original network producing the same excitation as did the original source. This is shown in Fig. 5*C*, and is analogous to the field problem of Fig. 2*C*. The condition analogous to the magnetic conductor of the field problem would be to replace the source impedance by an open circuit. It is then quite obvious that the current source alone is exciting the original network, producing the same excitation as did the original source. This is illustrated in Fig. 5*D*, and is analogous to the field problem of Fig. 2*D*. Note that Figs. 5*C* and 5*D* illustrate the usual concept of the compensation theorem.

Now consider the circuit analogue to the terminating currents. The original problem is taken the same as for the preceding case, redrawn in Fig. 6*A*. The second problem is set up as follows. A current source of excitation I is connected in parallel with the leads from the source to the network, but with the leads reversed from what they were in the equivalent source case. A voltage source is connected in series, but again with the leads reversed. (Thus, these sources are just the negative of those used in the preceding case.) The excitation of the original source is kept. This is shown in Fig. 6*B*. From circuit concepts, it can be shown that there is now no excitation of the original network, but that conditions within the source remain the same as in the original problem. Therefore, Fig. 6*B* is the circuit analogue to the field problem of Fig. 3*B*.

This time, since there is no excitation of the original network in the circuit of Fig. 6*B*, it can be replaced by any impedance desired without affecting conditions in the source. Thus, if it is replaced by a short circuit, the circuit of Fig. 6*C* is obtained. This is analogous to the field problem of Fig. 3*C*. Replacing it by an open circuit, the circuit of Fig. 6*D* is obtained. This is analogous to the field problem of Fig. 3*D*. Again, Figs. 6*C* and 6*D* are illustrations of the usual concept of the compensation theorem.

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Nuclear Power Plant Model

This nuclear power plant model built by North American Aviation for the U. S. Information Agency will be used as part of the official United States atomic energy exhibit, "Atoms for the Benefit of Mankind," at the Sao Paulo World Fair in Brazil this fall. Heat from atomic fission in the reactor core (1) is absorbed by liquid sodium and piped to a heat exchanger (2). Heat from first sodium system is transferred to secondary sodium system and carried to boilers to make steam (3). The steam is used to drive conventional turbogenerators to produce electricity (4)

Operational-Type Magnetic Amplifier

R. M. HUBBARD

THIS MAGNETIC AMPLIFIER has been developed to meet the need for a versatile, reliable, easily reproducible operational component for a low-level servo control system. The subject amplifier also exhibits unusual stability, linearity, and freedom from drift, which are requirements of prime importance in this particular application. The term "operational amplifier" as used herein describes an amplifier which can be used to perform various functions or operations without imposing its own characteristics on the system.

The extreme usefulness of this circuit is attested to by the fact that it has been possible to design a single basic amplifier with fixed, standard components which is used to perform such varied functions as mixing signals, changing impedance, adjusting gains, and driving hydraulic control valves. Furthermore, this basic "building block" amplifier lends itself admirably to various quantity production techniques.

The "operational amplifier" utilizes a familiar basic principle first applied to magnetic amplifiers by Geyger in his "self-balancing potentiometer" type circuits.[1] The addition of positive feedback and a novel stabilized self-bias circuit to a basic self-saturating amplifier produces a circuit having an effectively infinite internal gain which is stabilized by an adjustable external negative feedback. The fact that the negative feedback is introduced directly into the control winding to buck out the control current I_c gives this amplifier an extremely low input impedance.

An operational amplifier of the voltage output type and its equivalent block diagram appear in Fig. 1. If, as a result of the negative feedback, the current in the control winding (N_c) is zero, the output voltage E_o is given by the expression:

$$E_o = I_c R_s \tag{1}$$

It is the combination of extremely low input impedance and this linear gain function that has prompted the classification of this device as an "operational amplifier." It can be seen from the block diagram, for example, that

$$E_o = R_s(E_1/R_1 + E_2/R_2 + E_3/R_3 + \dots) \tag{2}$$

A simple change in the configuration of the negative feedback path will permit the same basic amplifier to provide a regulated current output.

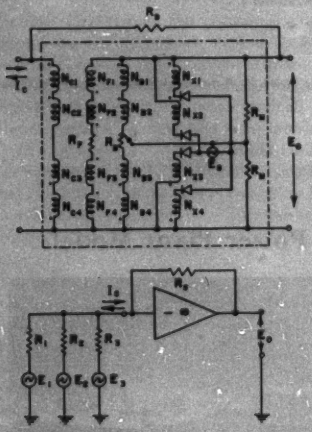

Fig. 1. Circuit diagram and equivalent block diagram for an operational magnetic amplifier of the voltage output type

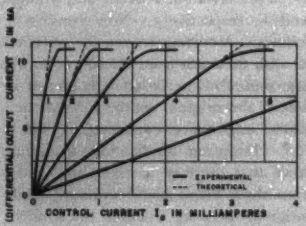

Fig. 2. Static transfer characteristics at various gain levels for an experimental operational amplifier of the current output type

In a practical circuit the idealized operating characteristics can only be approached. Methods have been developed for minimizing the amount that the control coil current departs from zero, and for determining the limitations imposed on the useful range of gains by this departure from the ideal. The transfer characteristics at various gain levels which were obtained with an experimental amplifier of the current-output type are shown in Fig. 2, together with those characteristics which are predicted by the theory.

This circuit incorporates a new type of self-bias which is relatively independent of supply regulation and rectifier leakage and has an inherent negative feedback effect. The use of this bias circuit (N_b) contributes greatly to the good stability of the amplifier and has the added advantage of minimizing the dissymmetry normally introduced by mismatch between pairs of cores.

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High-Pressure Pipe-Type Cable Systems

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PIPE-TYPE CABLES have in recent years become the most important means of bulk power transmission in locations where overhead lines are not permitted.

Articles have been published on many aspects of pipe cable work, but little has been written concerning the pipe as a structure. The present article treats this subject with reference to the selection of suitable pipe, the preparation of pipe ends for welding, methods of welding, and weld testing.

The selection of suitable pipe must take into account the need for steel of a weldable quality with sufficient ductility to permit bending and the flaring of the ends. It must have a wall thickness great enough to withstand the hoop stress produced by the internal pressure of the cable system's pressure medium.

Joining methods most favored are the flared-end and backing-ring method and the bell and spigot method. Backing rings must be used when the pipes are butt-welded to prevent weld metal from running into the pipes. Backing rings are not needed for bell and spigot joining, but fillet welds are fundamentally less strong than butt welds and cable may be pulled in only one direction.

Special welding fittings usually are chosen for underwater crossings where the inaccessibility of the pipe after installation justifies a more expensive fitting of maximum strength and providing a very smooth interior surface.

Qualification tests should be given to every welder. American Standards Association Standard *B-31.1* and The American Society of Mechanical Engineers Standard for Boilers, Section IX, are suitable for this purpose.

The objective in welding should be to obtain a weld which will match the quality of the pipe. The pipe ends should be carefully spaced before welding so that with the proper size welding rod good penetration will be obtained. Not less than three passes should be accepted for butt welds and four or five are usually employed in making fillet welds.

Not more than 1/8 inch of metal should be deposited on each pass and careful cleaning by chipping and wire brushing must be done after each pass before the succeeding pass is laid down.

Welding must not be done at temperatures below 40 F and accelerated cooling of a completed weld must never be permitted.

Electric arc welding generally is preferred to gas welding. Such welding may be done most rapidly by the downhand method, but extra skill is required because the molten metal tends to run down ahead of the arc entrapping slag and forming gas pockets.

Digest of paper 54-219, "High-Pressure Pipe-Type Cable Systems—The Pipe as a Structure," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Scheduled for publication in AIEE *Power Apparatus and Systems*, 1954.

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Welding rods designated by the American Welding Society as type *E-6010* are well suited to pipe-cable work. They may be used in any position with direct current, reversed polarity. They give deep penetration and the slag formed is thin and easily removed.

Welds may be tested individually by pressure tests or by X-raying. The use of "pigs," which permit an internal gas pressure to be applied between two tires positioned on either side of the weld, is the most common method of weld testing. The weld is immersed in water during the test and a leak would be detected by bubbles of nitrogen rising in the water bath.

An external tester has been under development by the Detroit Edison Company with very good results. A pressure of 900 pounds per square inch gauge is built up in the device which has been mounted over the weld and a loss of pressure, as shown by a dial gauge, would show the existence of a leak.

X-ray testing has the advantage of giving knowledge of the structural adequacy of the weld, as well as revealing leaks which might exist.

Pipe bending may be done easily in the field without damage to the pipe coating if the ambient temperature is 70 F or higher. In winter weather the pipe should be preheated. It is desirable that the radii of bends be above 40 feet. Where radii of 20 feet or less must be accepted, it will be found desirable to hot-bend the steel pipe to prevent excessive ovality or possible kinking.

Theoretically, temperature cycles could produce considerable thrust on cable pipes. At terminal ends this might put a strain on the potheads. To avoid this many companies have anchored the pipes near the terminals. Others have designed pothead mountings which can accommodate the movement. If a 90° bend exists near the terminal, it is probable that anchors will not be needed.

Practices vary regarding the depth of cover over pipes. Some companies have felt it to be important to have the pipes deep enough to avoid disturbance by others, such as water or sewer contractors, and have consequently required up to 6 feet of cover. Some have sought to provide mechanical protection by installing a concrete slab or creosoted planks over the entire length of the line. It is believed prudent to furnish some such protection if the pipes are exceptionally shallow. Steel plates or half-sections of a larger size pipe have been used where less than 24 inches of cover can be obtained.

To prevent corrosion of the pipe all users have utilized coated pipe. As a further safeguard some have distributed anodes along the line, while others have provided rectifiers and batteries for cathodic protection. Batteries will keep the pipe 2 volts negative with respect to earth. Sometimes it is preferable to have a lower voltage and means have been devised for doing this.

Economic Aspects of Using Electric Power For Waterflooding

FRANK BEACH

A specific oil field is selected to illustrate the comparison of electric power costs and those of gas engine operation in another field under similar waterflood conditions. The study indicates that electric power costs have been one half the cost of fuel for gas engine operation for equal volumes of fluid pumped, while manpower requirements were reduced 20 per cent due to electrification of six out of eight waterflood projects.

AFTER due consideration of the problems of discussing the economic aspects of using electric power for waterflooding, it was decided that perhaps the best way to illustrate this problem would be to discuss an actual waterflood project that has been equipped for electrical operation. The Madison Block in Greenwood County, Kans., has been chosen as an example. This field of 985 acres and 101 wells has run the full gamut of primary production, gas repressuring, and finally waterflooding.

Early primary production was pumped by large standard units. As production decreased the standard end units were removed and jacks and central powers were installed to pump the wells. Finally, as the waterflood development again increased production in excess of the capacity of the jacks, modern pumping units were installed to handle the larger volumes of fluid.

In 1948, the decision was made to convert the Madison Field to a waterflood project. It was realized that the development of this field as a waterflood project would require almost a complete replacement of all surface and pumping equipment in order to treat and handle the large volumes of injected and produced fluids.

Oil wells which were being pumped with jacks and central powers would be replaced with modern pumping units. Water supply sources would be developed and equipped to handle large volumes of fluids for injection and filter plants and pumps would be installed to treat and pump the injection water.

One of the first things that had to be considered was the kind of energy to be used for power. Although the Madison Field was under gas repressuring, it was realized that the produced gas would diminish quickly when waterflooding was started. A preliminary economic study was made which indicated that electrical operation would compare favorably with any other method of operation.

Full text of a paper presented at the AIEE Electrical Conference of the Petroleum Industry, Tulsa, Okla., September 27–29, 1954.

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Some of the factors that influenced the decision to use electric energy for waterflooding were as follows:

1. Electric power was readily available on the lease.
2. Power rates were favorable.
3. Electric prime movers were less than half the cost of internal combustion engines.
4. Electric motors were more adaptable to automatic operation and free wheeling.
5. Twenty-five to 35 per cent less labor was needed for operation than for gas engines.
6. Ninety-five per cent saving in maintenance labor over gas engines.
7. Expected smoother application of power for increased life of equipment.

FIELD APPLICATION OF ELECTRIC POWER

THE usual waterflood development program is to establish a pilot waterflood to determine whether the formation will flood successfully. Thereafter, if the pilot is successful the remainder of the development is made in successive stages of as much development as can conveniently be accomplished in a year's time. The Madison Block was developed under this system.

The pilot flood was started with five input wells in December 1948, with input water produced and pumped by gas-operated engines. The flood was gradually expanded until 1951 at which time many of the oil wells were producing beyond the capacity of the jacks and central powers. In December 1951, the first stage of the electric system was installed.

Electricity was purchased on the lease at a primary voltage of 12,400 volts. Primary lines were constructed to various points on the lease where transformers reduced the voltage to 440 volts for secondary transmission. Later as the flood progressed, additional electric lines were installed until the whole block was under electrical operation, see Fig. 1.

The electric motors required to power the various waterflood equipment are as follows:

3 60-hp motors to power high-pressure pumps in the filter plant
1 7½-hp motor for backwash pump
1 25-hp motor to power the turbine-type pump on the river
1 135-hp motor to power the Reda deep well pump
1 7½-hp motor to power a salt water disposal pump
1 7½-hp motor to power a fresh water supply pump
49 10-hp motors to power oil-well pumping unit

13 10-hp motors to power oil-well pumping units yet to be installed

A total of 70 electrical units with a combined 982½ hp will ultimately be required to handle the waterflood requirements of the Madison Block.

INVESTMENT COSTS FOR THE ELECTRIC SYSTEM

THE electrical investment costs for the Madison Field may be divided into two parts: the investment required for transmission lines, and that for prime movers. The cost of the entire field transmission system including poles, wire, transformers, and capacitators was $39,074.

The investment for prime movers including switch boxes, wiring, and installation labor is detailed as follows:

3	60-hp motors for hp pumps	$ 4,400
1	7½-hp motor for backwash pump	330
1	25-hp vertical motor for turbine pump	760
1	7½-hp motor for fresh water supply	330
1	7½-hp motor for salt water disposal pump	330
49	10-hp oil-well pumping unit motors	22,148
13	10-hp oil-well units to be installed	6,656
1	135-hp Reda pump installation	10,000
	Total estimated cost for prime movers	$44,954
	Total electrification cost	$84,028

It should be brought out at this point that the cost of electrification of any waterflood project will depend upon the spacing, depth of the producing sand, and thickness of the sand. This field is developed on a 20-acre waterflood spacing; that is, one input well to every 20 acres. Had the spacing been 10 acres, there would have been twice as many input wells and twice as many oil wells to pump. The input water would have been twice as great.

For the condition peculiar to the Madison Field, the cost per acre for electric installation is as follows:

Total developed acres	985
Cost per acre for transmission system	$ 39.67
Cost per acre for prime movers	$ 45.63
Total electrification cost per acre	$ 85.30
Total ultimate installed hp	982½
Cost per installed horsepower	$ 85.22
Total daily theoretical fluid capacity, barrels	75,056
Cost per barrel of capacity	$ 1.12
Total number of oil wells	62
Cost per oil well	$ 1,355

POWER COSTS IN RELATION TO VOLUME OF FLUID

A summary of electric power costs by years is as follows:

	Year	Kwh	Pf, Per Cent	Demand	Total Bill	Average Cost/Kwh
	1951	419,200	55	62- 93	$ 5,516	$0.013
	1952	1,190,400	71	154-214	12,868	0.011
	1953	2,541,200	77	345-449	25,653	0.010
4 mo.	1954	1,141,600	83	414-483	11,141	0.010

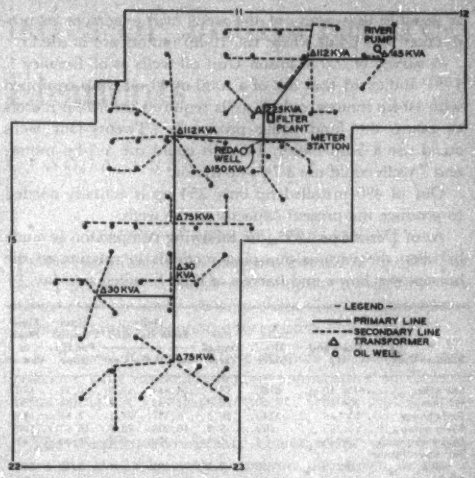

Fig. 1. Madison pool electric system, Greenwood County, Kansas

The total fluid handled by all electrical units with number of barrels handled per kilowatt-hour and the cost per barrel is compared as follows:

	Year	Barrels Total Fluid	Barrels/Kwh	Cost/Barrel
	1951	2,846,087	6.8	$0.0019
	1952	5,373,142	4.5	0.0024
	1953	8,176,912	3.2	0.0031
4 mo.	1954	2,986,277	2.6	0.0037

It is apparent that the fluid handled per kilowatt-hour has become less, and the cost per barrel of fluid handled has become higher. At the same time the power factor has improved and the relative demand has become less.

It is evident that the cause of the increased cost is due to the increasing number of pumping units installed over the period. Inspection of the installed horsepower hours in relation to the fluid handled indicates that the pumping units are far less efficient than other methods of pumping fluids. The reasons for this inefficiency are:

1. Fluctuating load conditions.
2. High fluid heads.
3. Friction lost in long rod strings.
4. Volume pumped limited to capacity of well to produce and not the pumping equipment.
5. Gas conditions in the well.

The low volume of fluid handled in relation to installed horsepower on pumping units suggests that perhaps the motors are too large for the volume of fluid being pumped.

A 10-hp motor should have the capacity to produce about 300 barrels of fluid per day from 1,900 feet. However, the average fluid pumped from Madison Unit wells is only 102 barrels per day per well. To pump 102 barrels of fluid would require only a 5-hp motor. However, it

is possible that many of the wells might increase in production to a point where the 10-hp motors are needed.

A survey of the Madison Unit oil wells as of January 1, 1954, indicated that out of a total of 49 oil wells equipped with 10-hp motors, only 3 wells required the 10-hp motors to pump the fluid being produced. Twenty-four wells could use a 5-hp motor, 15 wells could use a 3-hp motor, and 7 wells could use a $7\frac{1}{2}$-hp motor.

Out of 490 installed hp only 254 hp is actually needed to produce the present capacity of the wells.

As of December 1953, the following comparison is made between the various pumping methods in relation to the horsepower hours and barrels of fluid handled per day.

Kind of Unit	Units and Hp	Daily Hp Hours	Per Cent of Total	Daily Fluid Handled — Barrels	Per Cent	Fluid Pumped Per Hp Hour	Fluid Head in Pounds
Oil wells	49× 10 hp	8760	55	4,441	12.5	0.51	870
HP pumps	3× 60	3220	20.2	11,769	33.2	3.65	550
Reda pump	1×135	3240	20.3	8,531	24.1	2.63	695
River pump	1×25	600	3.8	10,000	28.2	16.67	100
Backwash pump	1×$7\frac{1}{2}$	4	0.1	300	0.8	75.00	45
Salt water disposal pump	1×$7\frac{1}{2}$	53	0.3	200	0.6	3.78	100
Fresh water pump	1×$7\frac{1}{2}$	53	0.3	200	0.6	3.78	100
Total	852	15,830	100.0	35,441	100.0	2.22	

It is evident from the above tabulation that the oil well units require 55 per cent of the total horsepower hours to pump only 12 per cent of the total daily fluid handled. Since there is more horsepower installed to power pumping units than for any other method of pumping, it is evident why the volume of fluid pumped per kilowatt-hour has decreased since 1951.

The schedule of horsepower installation is:

Date	PU	High P. Pumps	Back-wash	River Pump	House Water	Reda	Total
1951	86	120	$7\frac{1}{2}$	25	0	0	$238\frac{1}{2}$
1952	250	120	$7\frac{1}{2}$	25	0	0	$402\frac{1}{2}$
1953	367	180	$7\frac{1}{2}$	25	$7\frac{1}{2}$	105	699
4 mo. 1954	490	180	$7\frac{1}{2}$	25	$7\frac{1}{2}$	135	852

COST OF ELECTRICAL VERSUS GAS OPERATION

While it is not possible to make a comparison of the costs of operation between gas and electricity in the Madison Field, a comparison can be made between the Madison Field which is operated with electricity and the Patterson Block which is operated entirely with gas engines. The Patterson Block is a waterflood project of 200 acres producing from the same horizon and about the same depth (1,800 feet). Equipment investment cannot be compared because much of the equipment used on the Patterson Block was secondhand when installed. Also the gas fuel lines were already in place as gas gathering lines. The energy costs can be compared as follows:

Cost of Gas Versus Cost of Electricity

Year	Fluid Handled Barrels	Gas Fuel Cost	Gas Cost Per Barrel	Electricity Cost/Barrel
1951	4,085,724	$15,506*	$0.0038	$0.0019
1952	3,140,222	14,398	0.0046	0.0024
1953	2,468,522	16,555	0.0067	0.0031

* Average cost per thousand cubic feet of gas = 24.5¢.

It is evident that with gas at 24.5¢ per thousand cubic feet that electricity costs only about half as much to handle an equal volume of fluid under similar but not identical conditions.

Maintenance Costs

The major maintenance cost of electrical operation is due to motor burnouts caused by electrical storms.

A comparison for the year 1953 between the Madison motor repair costs and the Patterson engine maintenance costs is as follows:

Madison	$ 707*	42 units	All motors in field and plant
Patterson	1,006	29 units	Field engines (16 hp single-cylinder)
	3,523	4 units	Plant engines (40 hp 3-cylinder)
Total	$4,529		

* Labor and material.

The foregoing comparisons are indicative but not conclusive and are intended to show only in this specific case a comparison between gas engine and electric motor maintenance costs.

ELECTRIFICATION OF SECONDARY RECOVERY PROJECTS

Waterflood development was begun by Cities Service in 1936. The first three projects developed were operated with gas engines. It was soon found that the maintenance and operational labor required to operate a full-scale waterflood project with its many different powered units severely taxed the available manpower during the postwar years. Winter operation was especially difficult due to cooling system maintenance and ignition troubles with gas engines.

After the experience gained from the three initial projects, all subsequent waterfloods were equipped with electrically powered units. At the present time Cities Service has 16 waterflood projects on which are installed 476 electric-motor-driven units with a total installed horsepower of 8,476.

Before waterflood operations were started in the Madison District, the entire district employed 75 men to handle all of the leases in the area under stripper operations. Today, with operation and production expanded many times over stripper production which includes eight other waterflood projects with more individual pumping units and plants to operate, only 60 men are employed in the whole district. Most of this saving in labor is attributed to the use of electrically operated equipment.

Appendix. Madison Block Electric Power Cost Schedule

Demand	First 175 kva	1.40 per kva
	Next 425 kva	1.10 per kva
	Excess	0.90 per kva
Energy	First 50 kwh	$0.012
	Next 100 kwh	0.0085
	Next 250 kwh	0.0065
	Excess	0.0055

Minimum charge 50 per cent of 250 kva

3-phase alternating current 60 cycles—12,470 volts

Shaping the Characteristics of Temperature-Sensitive Elements

E. KEONJIAN J. S. SCHAFFNER

A method for shaping the characteristics of temperature-sensitive elements is described together with a practical example. The proposed method can be applied to any temperature-sensitive element provided that the coefficient of the temperature-sensitive element is larger than that of the desired characteristic and the characteristic of the temperature-sensitive element does not change with the applied voltage.

IN recent years, temperature-sensitive elements have found many useful applications, particularly in the field of control devices. In general, these elements are used in two ways:

1. In electric systems, controlled by changes in temperature.
2. As means for the compensation of undesirable effects caused in electric networks by temperature variations.

Usually, the characteristics of the commercially available temperature-sensitive elements do not have the form that is required for a specific application, therefore it may be necessary to use the temperature-sensitive element in combination with a passive shaping network which will modify its characteristic so that it has the desired form.

A method for calculating such shaping networks is given but it can be applied only to the case where the temperature of the temperature-sensitive element is equal to the ambient temperature. This implies that internal heating (due to current passing through the element) can be neglected. It is further assumed that for a given ambient temperature the resistance of the elements is constant and therefore it is independent of the current passing through them.

In Fig. 1 curve $r_{(T)}$ shows the temperature characteristic of the temperature-sensitive element alone while curve $R_{(T)}$ shows the desired characteristic that must be obtained by using this element in combination with a shaping network. It is assumed here that the shaping network consists of linear resistances only and that the temperature coefficients of these resistances can be neglected.

Revised text of paper 54-269, "Shaping of the Characteristics of Temperature-Sensitive Elements," recommended by the AIEE Committee on Electronics and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Published in AIEE *Communication and Electronics*, September 1954, pp. 396–400.

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The assistance of the staff of the electronics laboratory of the General Electric Company in Syracuse, N. Y., and in particular that of Dr. S. K. Ghandhi, is gratefully acknowledged.

TEMPERATURE-SENSITIVE ELEMENTS

IN the realization of the proposed method of temperature compensation, a number of temperature-sensitive elements may be used. Among these elements are special types of ceramic resistors and thermistors.

1. Ceramic Resistors. These resistors are made of compositions with marked negative temperature coefficients, (approximately 1 to 3 per cent per degree centigrade at 25 C).

The temperature-resistance characteristic of two commercially available ceramic resistors are shown in Fig. 2. It has been found empirically that these resistors obey an equation of the form

$$R = R_o e^{B\left(\frac{1}{T}-\frac{1}{T_o}\right)} \qquad (1)$$

In this equation, T_o is the reference temperature in degrees Kelvin (for 25 C, $1/T_o = 0.003356$), R the resistance at temperature T, R_o the resistance at reference temperature, T temperature of the resistor in degrees Kelvin, and B the temperature constant. A more convenient form of this equation for computation is

$$\text{Log}\frac{R}{R_o} = 0.4343\, B\left(\frac{1}{T}-\frac{1}{T_o}\right) \qquad (2)$$

The value of the constant B varies with the resistivity of the composition and can be obtained from the curves supplied by the manufacturer. A typical value of B is a few thousand degrees Kelvin.

The temperature coefficient a of these resistances can be calculated from equation 1

$$a = \frac{1}{R}\frac{dR}{dT} = -\frac{B}{T^2} \qquad (3)$$

A typical value for a at room temperature is 3 per cent per degree centigrade.

2. Thermistors. The word "thermistor" actually applies to any resistor which changes its resistance with temperature. Usage, however, has limited the term to resistors with negative temperature coefficients. Thus, the ther-

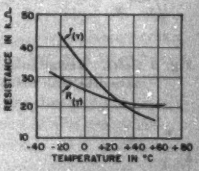


Fig. 1. Temperature characteristics of temperature-sensitive element and desired network

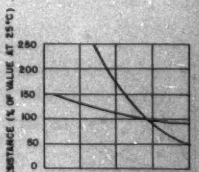


Fig. 2. Two typical resistance-temperature characteristics

mistor is a temperature-sensitive resistor consisting of a sintered combination of ceramic materials and various metallic oxides. The temperature coefficient of thermistors is negative and is of the order of 2.5 per cent per degree centigrade at 20 C. Fig. 3 shows the temperature characteristic of one of the commercially available thermistors, having a temperature coefficient of −2.7 per cent at 20 C. The resistance of these thermistors can be calculated for any given temperature using equations 1 and 2.

SHAPING NETWORK WITH TWO AND THREE FIXED RESISTANCES

Two possible arrangements of shaping networks with two fixed resistors R_1 and R_2 and one temperature-sensitive element are shown in Fig. 4. The total resistances R of these networks (measured between points A and B) is

for Fig. 4A

$$R=\frac{R_1R_2+r(R_1+R_2)}{R_2+r} \tag{4}$$

for Fig. 4B

$$R=\frac{R_1R_2+rR_1}{R_1+R_2+r} \tag{5}$$

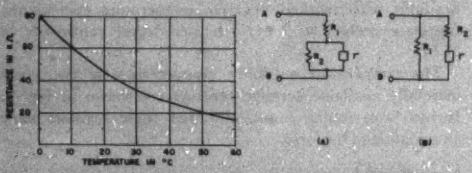


Fig. 3 (left). Temperature characteristic of commercially available resistance. Fig. 4 (right). Shaping networks with two fixed resistances R_1 and R_2

It should be noted that the variation of R with temperature will always be smaller than the corresponding variation of r alone, since the networks contain passive resistances in series and parallel with the temperature-sensitive element. It is also obvious that an increase in $r_{(T)}$ will always cause an increase in $R_{(T)}$; and a decrease in $r_{(T)}$ a decrease in $R_{(T)}$. Mathematically this may be expressed as

$$0\leqslant dR/dr\leqslant 1 \tag{6}$$

The equations 4 and 5 are of the general form

$$R_{(T)}=\frac{a+br_{(T)}}{c+r_{(T)}} \tag{7}$$

with positive coefficients a, b, and c. Geometrically this corresponds to rectangular hyperbolas of the form shown in Fig. 5. This property will be used in the future discussion.

Fig. 6 shows two possible arrangements of shaping networks with three fixed resistances R_1, R_2, and R_3 and a temperature-sensitive element r.

The total resistance R of these networks, measured between points A and B is

for Fig. 6A

$$R=R_3+\frac{R_1R_2+r(R_1+R_2)}{R_1R_3+R_2R_3+r(R_1+R_2+R_3)} \tag{8}$$

for Fig. 6B

$$R=\frac{(R_1R_3+R_1R_3+R_2R_3)+r(R_1+R_3)}{R_1+R_3+r} \tag{9}$$

The inequality 6 holds for equations 8 and 9 also and likewise their general form is that of equation 7.

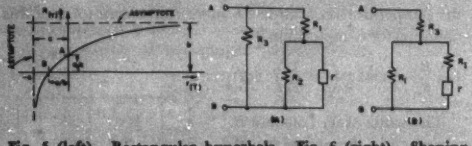


Fig. 5 (left). Rectangular hyperbola. Fig. 6 (right). Shaping networks with three fixed resistances R_1, R_2, and R_3

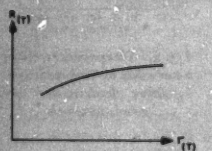


Fig. 7. The variation of $R_{(T)}$ as a function of $r_{(T)}$

CRITERIA FOR POSSIBLE SHAPING ARRANGEMENTS

If $R_{(T)}$ is the desired temperature characterisic and $r_{(T)}$ the characteristic of the temperature-sensitive element alone (see Fig. 1), then $R_{(T)}$ may be represented as a function of $r_{(T)}$, thereby eliminating the temperature as variable. Fig. 7 shows such a characteristic in a plane with $r_{(T)}$ as abscissa and $R_{(T)}$ as the ordinate. In the previous section it was shown that the relationship between $R_{(T)}$ and $r_{(T)}$ for shaping networks consisting of two or three externally added resistances can be expressed by the equation of a rectangular hyperbola, equation 7.

The asymptotes of this hyperbola are: $R_{(T)}=b$ and $r_{(T)}=-c$. As may be seen, this hyperbola intersects the $R_{(T)}$ axis at a point $A=a/c$ and the $r_{(T)}$ axis at a point $B=-a/b$. The basic problem of obtaining a desired temperature characteristic $R_{(T)}$ with a given temperature-sensitive element and a number of externally added resistances may now be reduced to that of approximating

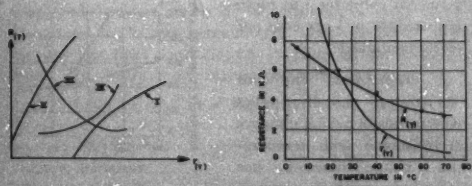


Fig. 8 (left). Undesirable characteristics. Fig. 9 (right). Resistance versus temperature characteristics

the curve of Fig. 7 by a rectangular hyperbola as shown in Fig. 5.

A good approximation, however, is not possible in a number of cases. For example, this is true for the characteristic *III* of Fig. 8 since this characteristic has a negative slope and for the characteristic IV in the same figure since the latter is curved upward instead of downward. The curve *I* has a positive intersect with the $r_{(T)}$ axis and the curve *II* has a slope larger than unity. In all such cases, where the curve corresponding to a given $R_{(T)}$ and $r_{(T)}$ cannot be approximated readily by a rectangular hyperbola of the type shown in Fig. 5, a new temperature-sensitive element with a different characteristic should be selected.

SYNTHESIS OF TEMPERATURE-SENSITIVE NETWORKS

In the following a method will be described for constructing a shaping network with a $R_{(T)}-r_{(T)}$ characteristic that has at least three points in common with the desired characteristic. Since the characteristic of the shaping network is a hyperbola and the desired characteristic may have a considerably different form, the two curves may not generally be expected to have more than three points in common.

In order to approximate a desired temperature characteristic in the $R_{(T)}-r_{(T)}$ plane, three points on this characteristic must be selected. Then a rectangular hyperbola passing through these three points should be constructed. A graphical method for this construction is described in the appendix. The coefficients a, b, and c of equation 7

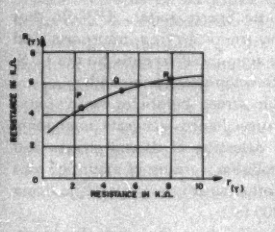


Fig. 10 (left). The $R_{(T)}-r_{(T)}$ characteristic. Fig. 11 (right). Construction of the hyperbola

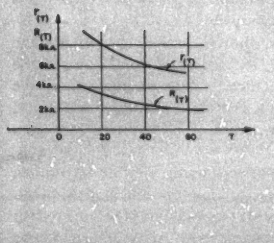
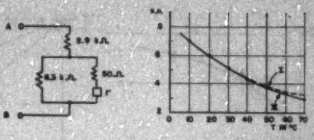


Fig. 14 (left). $R_{(T)}$ and $r_{(T)}$ characteristics. Fig. 15 (right). Construction of $R_{(T)}-r_{(T)}$ characteristic

Fig. 12 (right). Actual shaping network. Fig. 13 (far right). Comparison of desired and actual characteristics



describing the hyperbola are determined by the co-ordinates of the origin of the hyperbola and its intersects with the abscissa and ordinate, see Fig. 5.

Knowing these coefficients, the elements of the shaping network can be calculated for example by comparing equations 7 and 9. These two equations are identical if

$$\begin{aligned} a &= R_1R_2+R_1R_3+R_2R_3 \\ b &= R_1+R_3 \\ c &= R_1+R_2 \end{aligned} \qquad (10)$$

The values of R_1, R_2, and R_3 are therefore

$$\begin{aligned} R_1 &= \sqrt{bc-a} \\ R_2 &= c-R_1 \\ R_3 &= b-R_1 \end{aligned} \qquad (11)$$

PRACTICAL EXAMPLES

An example of the two curves, one representing the characteristic of the temperature-sensitive element alone, $r_{(T)}$, the other, the desired temperature characteristic, $R_{(T)}$, is shown in Fig. 9.

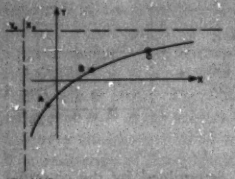
From these two curves, the characteristic in the $R_{(T)}-r_{(T)}$ plane may be obtained as shown in Fig. 10. As shown previously, this curve should be approximated by a rectangular hyperbola in order to obtain the necessary design information for the shaping network. In Fig. 11 three points of the $R_{(T)}-r_{(T)}$ characteristic have been selected and a rectangular hyperbola passing through these points has been constructed. (See techniques of this construction in the appendix.) The asymptotes of this hyperbola are $R_{(T)} = 9.2\text{K}\Omega$ and $r_{(T)} = -6.25\text{K}\Omega$ and the intersection with the $R_{(T)}$ axis is $R_{(T)} = 2.9\text{K}\Omega$. The coefficients a, b, and c of the equation 7 are therefore

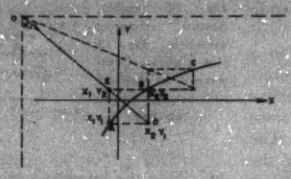
$$a = 18.4(\text{K}\Omega)^2;\ b = 9.2\text{K}\Omega;\ c = 6.25\text{K}\Omega$$

For a shaping network as shown in Fig. 6*B*, the values of the resistances R_1, R_2, and R_3 can be calculated from equation 11

$$\begin{aligned} R_1 &= \sqrt{bc-a} = 6.3\text{K}\Omega \\ R_2 &= c-R_1 = 50\Omega \\ R_3 &= b-R_1 = 2.9\text{K}\Omega \end{aligned}$$

Fig. 12 shows the complete network. The temperature characteristic of this network is indicated as curve *I* in Fig. 13. Curve *II* of the same figure represents the desired





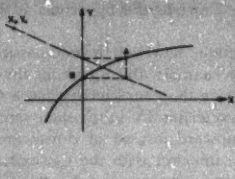


Fig. 16 (left). Rectangular hyperbola. Fig. 17 (center). Method of graphical construction. Fig. 18 (right). Construction of intersection with y-axis

characteristic. Comparing the two curves it may be seen that the approximation is close.

A case where $r_{(T)}$ and $R_{(T)}$ are of different orders of magnitude is shown in Fig. 14.

Fig. 15 shows the $R_{(T)}-r_{(T)}$ characteristic and the hyperbola approximating it.

Appendix. A Method for Constructing a Rectangular Hyperbola From Three Given Points

A rectangular hyperbola with the origin as the center is

$$xy=a \tag{12}$$

If the center is at $x=x_0$, $y=y_0$, this equation is

$$(x-x_0)(y-y_0)=a$$

or

$$y=y_0+\frac{a}{x-x_0}=\frac{y_0x+(a-x_0y_0)}{x-x_0} \tag{13}$$

Fig. 16 shows such a hyperbola. In the following a method will be given by which the hyperbola can be constructed, and in particular the point x_0y_0 found if three points of the hyperbola (for example A, B, and C in Fig. 16) are known. Let the co-ordinates of A, B, and C be x_1y_1, x_2y_2, and x_3y_3 respectively.

First it shall be proved that the line connecting the points E and D of Fig. 17 passes through the point x_0y_0 where E and D have the co-ordinates y_2x_1 and y_1x_2 respectively.

The equation of this line is

$$y=y_1-\frac{(y_2-y_1)(x-x_2)}{x_2-x_1}$$

Replacing y_1 and y_2 by

$$y_1=y_0+\frac{a}{x_1-x_0} \qquad y_2=y_0+\frac{a}{x_2-x_0}$$

gives

$$y=y_0+\frac{a(x-x_0)}{(x_1-x_0)(x_2-x_0)} \tag{14}$$

For $x=x_0$, $y=y_0$. The dotted line of Fig. 17 therefore passes through the point x_0y_0.

The method of construction of the point $x=x_0$, $y=y_0$ from three points A, B, C of the hyperbola based on this is obvious from Fig. 17 where two rectangles are constructed using the known points A, B, and C as corners. The two diagonals of these rectangles must both pass through x_0y_0. The point where they cross is therefore x_0y_0.

In the following, the graphical construction of the intersection point of the hyperbola with the y axis is given. (See Fig. 18.) In this figure, the intersection of the hyperbola with the y axis should be found. First a parallel to the x axis is drawn through the known point A. Then a line is drawn from x_0y_0 through the intersection of the y axis and this parallel. A rectangle with this line as a diagonal is then constructed as indicated in Fig. 18. The corner B of this triangle is the intersection of the hyperbola with the y-axis.

If the asymptotes and at least one point, Q of a hyperbola, are known then further points can be constructed by the method indicated in Fig. 19. A line is drawn through the known point Q, intersecting both asymptotes in points N and M. A second point of the hyperbola can then be found by locating a point P on the line so that $PN=QM$. Additional points may be found by the same method by drawing a different line through Q (or P) using the same techniques. (See construction of point R in Fig. 19.)

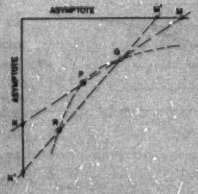


Fig. 19. Construction of hyperbola

Reference

1. Les Propriétés et les Applications des Thermistances (Properties and Applications of Thermistors), J. Bleuse. *Onde Électrique*, Paris, France, no. 317–18, August-September 1953, pp. 497–509; no. 319, October 1953, pp. 578–90.

Airborne Radar

A new, compact airborne Sperry radar, *APN-59*, that assures greater safety for troop-carrying transports and essential cargo planes was announced recently by the U. S. Air Force Research and Development Command.

The single 5-inch radar screen combines many radar functions of search and surveillance, accurate nagivation over uncharted airlanes, detection of distant storms and best-weather routes, anticollision warning of mountain tops and tall structures, or of other nearby aircraft while flying at any altitude up to 50,000 feet.

Exceptional performance in these life-saving functions, already tested and proved by the Air Force, is achieved by a single lightweight system weighing 150 pounds. This includes an oddly-shaped "turtle shell" antenna only 18 inches in size, that is gyrostabilized for positive steadiness against pitch and roll of the plane.

Earlier test sets proved that the new *APN-59* has the power, despite small size, to "see" all around one of the Great Lakes at a single "glance." One photo taken off the radar screen clearly shows Buffalo, Detroit, Toledo, and Toronto at opposite extremities of Lake Erie, 250 miles apart.

A wide choice of range scales for the viewing screen can be selected by the operator for close-up enlargements variable from 3 to 30 miles, or for fixed ranges of wider areas at 50, 100, and 240 miles. Areas shown may be oriented to current heading of the aircraft, or optionally to true North or any desired compass bearing for measurement of drift.

E-Type Telephone Repeaters

J. O. SMETHURST

THE INSERTION of repeaters into telephone lines to make up for circuit losses is a very common practice today. The use of negative impedance to overcome transmission loss is an old idea but only recently used to any great extent in the exchange area plant. A series type of negative impedance repeater, called the *E1* telephone repeater, has found favor in the Bell System and its use has stimulated a demand for still more economical designs including a companion shunt type of negative impedance repeater. Through the use of these new *E*-type repeaters, it is possible to reduce the attenuation and improve the return loss of voice-frequency lines so that exchange area trunks can be used as links in a toll connection.

Rather than adapt some form of modification to the existing *E1* repeater design, many advantages are obtained by producing a new series type of negative impedance device called the *E2* repeater and a new shunt type of negative impedance unit called the *E3* repeater shown in Fig. 1. New equipment designs will reduce the maintenance, obtain a substantial reduction in price, and make more efficient use of the central office space.

The *E2* telephone repeater is designed to generate a negative impedance which may be connected in series with a telephone trunk to reduce the transmission losses. The repeater consists of an input transformer, connected in series with the telephone line, a push-pull amplifier, and a variable gain-adjusting network. A stable series type of negative impedance is obtained by maintaining the correct proportions of positive and negative feedbacks. The magnitude and phase of the negative impedance is a function of the network impedance Z_N and the final negative impedance presented to the line is equal to $-0.1Z_N$ over the frequency band of 300 to 3,500 cycles for values of negative impedances between -100 and $-2{,}000$ ohms.

Fig. 1. Shelf of E2 and E3 repeaters

Fig. 2. E Repeater Test Set model

The *E3* telephone repeater is designed to generate a shunt type of negative impedance which can be used with an *E1* or *E2* repeater for obtaining higher gains and improving the return losses of telephone trunks. The repeater consists of a variable gain-adjusting network, a 2-stage vacuum-tube amplifier, and an output bridge in which the line and network circuits are involved as two of the ratio arms. Stable conversion of the network impedances is obtained by unbalancing the bridge in the direction to apply negative feedback to the amplifier circuit. The magnitude and phase of the shunt type of negative impedance is a function of the network impedance Z_N. The final negative impedance presented to the line is equal to $-1/0.94Z_N$ over the frequency range of 300 to 3,500 cycles for values of impedance between -200 and $-3{,}000$ ohms.

A new *E* Repeater Test Set, shown in Fig. 2, has been developed for testing and maintaining the *E1*, *E2*, and *E3* telephone repeaters. All test connections which are required to measure individual repeaters or combinations of repeaters are made by the operation of a single control rotary function switch. The resulting simplification will reduce the effort required for installing, testing, and maintaining these repeaters. The test set includes means for measuring the transmission and stability of the repeaters, the impedance of the repeaters or lines, and the return loss between any two impedances. The magnitude and phase angle of the impedances are determined by simple transmission measurements.

Digest of paper 54-287, "*E*-Type Telephone Repeaters—Description, Equipment, and Testing," recommended by the AIEE Committee on Wire Communications Systems and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Summer and Pacific General Meeting, Los Angeles, Calif., June 21–25, 1954. Scheduled for publication in AIEE *Communication and Electronics*, 1954.

J. O. Smethurst is with Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Carrier-Current Line Trap for Power Lines

F. D. JOHNSON
MEMBER AIEE

E. W. LINDSAY
ASSOCIATE MEMBER AIEE

ZENO NERI
ASSOCIATE MEMBER AIEE

CARRIER-CURRENT line traps first were proposed about 1928 as a means of reducing carrier-current signal dissipation over undesired lines of power systems. Their use for this purpose has increased steadily with the increasing complexity of the power-line circuits upon which carrier is used. That line traps have done an effective job is attested by the fact that carrier systems are functioning more economically and more reliably with the use of steadily decreasing transmitter powers.

A new carrier-current line trap has been developed in 1,200-, 800-, and 400-ampere ratings, as shown in Fig. 1. The respective short-circuit abilities are 36,000, 20,000, and 15,000 amperes for 2 seconds. The first half-cycle of these short-circuit currents may be fully offset with resultant current crests 2.83 times the values given.

There was a time when line traps were applied as an afterthought; in other words, as trouble spots developed on a carrier system, traps were added. By present practice, traps are largely an anticipated item. By this means, traps can be applied to lines having known low impedance as well as to those of supposed high impedances at specific frequencies, and with the trap in place there is an impedance below which it is known the line cannot go, regardless of circuit switching combinations.

The impedance of a line trap in the region of resonance is its most important quality. This impedance is proportional to the main coil inductance, and hence the main coil is a most important element of the trap. This coil is approximately 260 microhenrys in value, the maximum impedance consistent with cost, size, weight, and short-circuit ability.

In the United States, line traps commonly are designed to obstruct one or two specific frequencies of each trap. Band blocking traps are feasible theoretically but considerations of size, cost, high inductance, and limited short-circuit ability curtail their application.

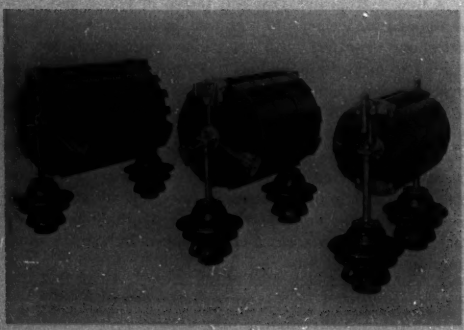


Fig. 1. The new carrier-current line trap, in 1,200-, 800-, and 400-ampere ratings

Radio influence tests for system voltages to 345 kv have been made, with no visible or audible corona. For 230 kv and higher, corona shields are used on the terminals as shown on the 400-ampere trap of Fig. 1.

The main coil consists of 2-stranded copper conductors, wound helically, coaxially, and in parallel, embedded in molded resin posts, to provide rigid conductor spacing during short circuits.

The coil is supported in compression between two galvanized, nonmagnetic steel end brackets. The internal tension members are composed of bronze bolts with porcelain insulators in compression. The trap terminals are rigidly fastened to the steel end brackets, to prevent bending or damage due to mechanical forces during short circuit.

Traps for application with a single carrier frequency carry one tuning unit. Traps for application with two carrier frequencies carry three tuners. Fine adjustment of tuning is by means of tapping of the turns of the main coil. The tuning capacitors use polytetrafluoroethylene film impregnated with oil as the dielectric material. The change of capacitance with temperature variation from −40 to +40 C is less than 3 per cent. This compares favorably with the accepted variation of 4 per cent for such capacitors, which in terms of tuned frequency is a change of 2 per cent.

Commonly the line trap is built and used with the high Q or sharp type of tuning. This is ideally suited for use with narrow-band channels such as used for relaying, telemetering, and supervisory control. However, for use in trapping modulated waves, such as in voice communication, the trap is available with a relatively low Q. This low Q trap has a much less sharp impedance curve in the region of resonance, and the resistive component is even less sharp than is the case for the high Q trap. It is of importance that the resistive component for several per cent off resonance is significantly larger for the low Q trap than it is for the high Q trap.

To give adequate impedance coverage over the region adjacent to resonance, it is recommended in the case of traps tuned for two frequencies that the two frequencies be separated by 25 kc or 25 per cent of the higher frequency, whichever is greater.

Digest of paper 54-85, "A New Carrier-Current Line Trap for Power-Line Application," recommended by the AIEE Committee on Carrier Current and approved by the AIEE Committee on Technical Operations for presentation at the AIEE Winter General Meeting, New York, N. Y., January 18–22, 1954. Published in AIEE *Power Apparatus and Systems*, June 1954, pp. 578–82.

F. D. Johnson, E. W. Lindsay, and Zeno Neri are with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

The authors wish to express to R. E. Marbury their appreciation of his many ideas and his untiring efforts in guiding the development of this series of line traps.

INSTITUTE ACTIVITIES

Fall General Meeting Features Air Transportation and Rotating Machinery

Chicago, the center of one of the greatest diversified industrial areas in the world, has been chosen for the 1954 AIEE Fall General Meeting. The technical program, inspection trips, and social events will occupy the entire facilities of the Morrison Hotel, meeting headquarters for the complete five days, October 11–15, 1954.

This program is the largest since these Midwestern meetings were instituted which is due to the central location of Chicago and its accessibility by air and rail from all parts of North America.

TECHNICAL SESSIONS

Special attention is being given to air transportation and rotating machinery. Eight and seven sessions respectively are scheduled on these two subjects, Monday through Friday. Other papers will cover subjects in all fields of the electrical industry.

The increasing interest in 277/480 volts as a standard secondary voltage has resulted in plans for a joint symposium of the Transmission and Distribution Committee with the Committee on Industrial Power Systems. This will consist of a series of technical and conference papers dealing with many phases of the problem. Special Publication *S-66* containing these papers is available from the AIEE Order Department. Price $2.00 per copy.

A report prepared by Edison Electric Institute and AIEE covering an extensive questionnaire dealing with practices on distribution protection will be presented, and will be supplemented by a series of conference papers on the same subject. This is a joint activity of the Transmission and Distribution Committee with the Committee on Relays.

SOCIAL ACTIVITIES

Get Acquainted Tea. On Sunday afternoon from 4:00 to 6:00 p.m. there will be an informal tea for early arrivers. Members and their wives are cordially invited to attend the tea.

A Smoker for the members has been planned for Tuesday evening, October 12. A dinner and a fine program of entertainment will be preceded by a hospitality hour. Address requests for tickets to: J. A. Romano, Delta Electric Company, 2437 Fulton Street, Chicago 12, Ill. All requests should be accompanied by a remittance of $10.00 to insure a reservation.

Dinner Dance. Wednesday evening, dinner in the Ballroom has been planned for members and their wives. The dance will be preceded by a social hour. Formal dress is optional. Tickets are $8.00 per person and may be purchased in advance by writing to E. R. Whitehead, Chairman, AIEE Dinner Dance Committee, Illinois Institute of Technology, 3300 Federal Street, Chicago 16, Ill.

ETA KAPPA NU ACTIVITIES

This year is the fiftieth anniversary of the founding of Eta Kappa Nu Association, electrical engineering honor society. A Golden Jubilee Celebration will be held on the University of Illinois campus at Urbana

Courtesy Kaufmann and Fabry Company

View of the Lake Michigan waterfront and skyline of Chicago, where the AIEE Fall General Meeting will be held, October 11–15.

Future AIEE Meetings

AIEE - IRE - RETMA - SMPTE - National Electronics Conference
Hotel Sherman, Chicago, Ill.
October 4–6, 1954
(*Final date for submitting papers—closed*)

Middle Eastern District Meeting
Abraham Lincoln Hotel, Reading, Pa.
October 5–7, 1954
(*Final date for submitting papers—closed*)

Fall General Meeting
Morrison Hotel, Chicago, Ill.
October 11–15, 1954
(*Final date for submitting papers—closed*)

Machine Tool Conference
Hotel Statler, Detroit, Mich.
October 25–27, 1954
(*Final date for submitting papers—closed*)

Mid-Atlantic Textile Conference
North Carolina State College, Raleigh, N. C.
November 4–5, 1954
(*Final date for submitting papers—closed*)

AIEE-IRE Conference on Electrical Techniques in Medicine and Biology
Morrison Hotel, Chicago, Ill.
November 10–12, 1954
(*Final date for submitting papers—closed*)

AIEE-IRE-ACM Eastern Computer Conference
Bellevue-Stratford Hotel, Philadelphia, Pa.
December 8–10, 1954
(*Final date for submitting papers—closed*)

AIEE - IRE - NBS High-Frequency Measurements Conference
Hotel Statler, Washington, D. C.
January 17–19, 1955
(*Final date for submitting papers—October 18*)

Winter General Meeting
Hotel Statler, New York, N. Y.
January 31–February 4, 1955
(*Final date for submitting papers—October 20*)

Utilization of Aluminum Conference
William Penn Hotel, Pittsburgh, Pa.
March 15–17, 1955
(*Final date for submitting papers—December 15*)

Materials Handling Conference
Hotel Cleveland, Cleveland, Ohio
March 28–29, 1955
(*Final date for submitting papers—December 28*)

Southern District Meeting
St. Petersburg, Fla.
April 13–15, 1955
(*Final date for submitting papers—March 29*)

Electric Heating Conference
LaSalle Hotel, Chicago, Ill.
May 10–11, 1955
(*Final date for submitting papers—February 10*)

1955 Summer General Meeting
New Ocean House, Swampscott, Mass.
June 27–July 1, 1955
(*Final date for submitting papers—March 29*)

An inspection trip will be to Delta Star Electric Company. Shown above is the department where high-tension disconnect switches are manufactured

the weekend of October 15–16 with most of the alumni activity on Saturday.

A fitting program to commemorate the fiftieth anniversary of Eta Kappa Nu is planned for these days, with many events scheduled that will interest not only all members but their families as well.

Additional information on this program can be obtained by writing Professor D. S. Babb, 155 Electrical Engineering Building, University of Illinois, Urbana, Ill. Also see p. 947.

LADIES PROGRAM

Mrs. Roger R. O'Conner and her committee have plans for many interesting activities and trips for the ladies including a "you pick it–we'll take you" promise. Tours are planned to: St. Peter's Cathedral, Board of Trade, Hull House, night tour of Chicago, Swift and Company, Kungsholm Restaurant for dinner and famous Miniature Grand Opera, and the North Shore as far as the Bahai Temple.

Free radio and television tickets will be available for all days of the convention. Breakfast Club television broadcast tickets will be available. This broadcast is from the convention headquarters hotel. It is the coast-to-coast Don McNeil show that went on television this spring.

Coffee Hours. From 9:00 to 10:30 a.m. coffee and rolls will be served each morning in the Ladies Headquarters. Hostesses will be there to explain the program and help the ladies choose their entertainment for the day.

You Pick It-We'll Take You. Ladies are invited to name the places they would like to visit and hostesses will be available to help arrange the trips of their choice. Among these might be: Chicago Historical Society, Chicago Museum of Science and Industry with Coleen Moore's Doll House, Chicago Art Institute, Adler Planetarium, Shedd Aquarium, Chicago Natural History Museum, and retail stores Marshall Field and Company, Carson Pirie Scott and Company, and others.

(*Continued on page 944*)

Tentative Technical Program

Fall General Meeting, Chicago, October 11–15

Monday, October 11

10:00 a.m. General Session

Address of Welcome. John W. Evers, president, Commonwealth Edison Company

Your Institute—Its Problems, President A. C. Monteith

Technology in Defense, Donald A. Quarles, Assistant Secretary of Defense

2:00 p.m. Air Transportation

54-355. Correlation of Rating Data for Rotating Electrical Machinery. *E. O. A. Naiman*, Wright-Patterson Air Force Base

54-346. Ten Years of Progress in Predicting the Aerodynamic, Thermodynamic and Output Characteristics of Blast-Cooled Aircraft Generators. *D. H. Scott*, Naval Research Laboratories

54-414. Thermal Developments in Aircraft Generators. *C. G. Martin*, Jack and Heintz, Inc.

54-415. High Altitude Aircraft Inverters. *P. W. Franklin*, The Leland Electric Company

2:00 p.m. Carrier Current

54-321. A Study of the Use of Tone Modulation over Complex Carrier Channels. *J. C. G. Carter*, Westinghouse Electric Corporation

Application of Microwave Equipment to Power Systems

This will be a group discussion covering application problems and experiences with microwave equipment guided by a panel composed of both users and manufacturers of microwave equipment.

2:00 p.m. Induction Machinery

CP.* Dynamic Braking of Induction Motors with D-C Excitation. *C. T. Button*, National Pneumatic Company, Inc.

54-323. Nonuniform Torque in Induction Motors Caused by Unbalanced Rotor Impedances. *O. I. Elgerd*, Washington University

54-349. Internal Fault Currents in Multi-Circuit Induction Machines. *D. L. Lafuse*, General Electric Company

54-381. An Equivalent Thermal Circuit for Non-Ventilated Induction Motors. *R. L. Kosik*, Reliance Electric and Engineering Company

CP.* Predicting Temperature Rise in Electric Motors by the Use of an Equivalent Circuit. *W. J. Wittke, C. H. Crouse*, Robbins and Myers, Inc.

2:00 p.m. Magnetic Amplifiers

54-375. Derivative Controlled Magnetic Amplifiers. *A. D. Schnitzler*, Naval Research Laboratory

54-364. The Biased Rectifier Amplifier—A Pulse Magnetic Amplifier. *R. E. Morgan*, General Electric Company

54-388. Saturating Transformer Reference Circuit. *W. G. Evans*, Westinghouse Electric Corporation

54-376. Alteration of the Dynamic Response of Magnetic Amplifiers by Feedback Techniques. *R. O. Decker*, Westinghouse Electric Corporation

54-389. An Analogue Computer Technique Using Magnetic Amplifiers. *B. E. Davis, I. H. Swift*, Naval Ordnance Test Station

2:00 p.m. Metallic Rectifiers

CP.* Power Germanium Rectifiers for a High Current and Voltage Surge Application. *E. F. Lasso, H. R. Camp*, Westinghouse Electric Corporation

54-416. A Magnetically Regulated Portable Battery Charger. *R. E. D. Anderson*, Bell Telephone Laboratories, Inc.

54-417. The Suitability of the Silicon Alloy Junction Diode as a Reference Standard in Regulated Metallic Rectifier Circuits. *D. H. Smith*, Bell Telephone Laboratories, Inc.

54-418. Some Applications of Semiconductor Devices in the Feedback Loop of Regulated Metallic Rectifiers. *B. H. Hamilton*, Bell Telephone Laboratories, Inc.

CP.* Review of AIEE Metallic Rectifier Standards. *E. A. Harty*, General Electric Company

2:00 p.m. Instrumentation

CP.* Discussion of Precision in a Meter Checking Program. *R. E. McCallum*, Sandia Base

54-354. A New Standard for Direct Current. *F. C. Fitchen, F. P. Schwieg, W. H. Tucker*, General Electric Company

CP.* A Symmetrical Component Synthesizer and Analyzer. *E. B. Kurtz, C. R. Lodge*, State University of Iowa

CP.* A New Electrical Hygrometer. *W. C. White*, General Electric Research Laboratories

Tuesday, October 12

9:00 a.m. Industrial Power Systems, Transmission and Distribution, Production and Application of Light

54-329. Current Distribution in Paired-Phase Bus Bars Under Unbalanced Load Conditions. *J. B. Cataldo, N. Shackman*, BullDog Electric Products Company

54-333. A Field Method for Determining the Leading and Lagging Regulator in an Open Delta Connection. *H. S. Lokay, R. L. Custard*, Westinghouse Electric Corporation

S-66. Network Application at 277/480 Volts for a Medium Density Area. *E. A. Rathfon*, Commonwealth Associates, Inc.; *J. R. Oberholtzer*, Commonwealth Services, Inc.; *W. R. Fulch*, Central Illinois Light Company

* CP: Conference paper; no advance copies are available; not intended for publication in *Transactions*.

CP.* Hi-Volt-Cycle Lighting is Launched in a Hi-Wide Building. *J. H. Campbell, H. D. Kurt, H. E. Schultz*, General Electric Company

9:00 a.m. Electrical Safety in College Laboratories

CP.* The Need for Education in the Field of Safety. *R. C. Peterson*, Illinois Institute of Technology

CP.* Problems of Safety in College Electrical Laboratories. *M. S. Coover*, Iowa State College

CP.* Safety in Electrical Laboratories. *R. L. Lloyd*, National Bureau of Standards

CP.* Psychological Aspects of Accident Prevention *M. S. Viteles*, Philadelphia Electric Company

9:00 a.m. Air Transportation

54-356. Carbon Pile Regulator Theory, Calibration, Adjustment and Factors Affecting its Operation. *H. H. C. Richards*, Westinghouse Electric Corporation

CP.* A Static Exciter for Aircraft AC Generators *D. G. Seorgis*, Naval Research Laboratories

CP.* Results of a Transient Stability Study on an Aircraft-Type Single-Phase AC System. *H. B. James*, Westinghouse Electric Corporation

54-419. A High-Power Servo Analyzer. *Sterling Gorrill*, Hanson-Gorrill-Brian, Inc.; *O. C. Walley*, Jack and Heintz, Inc.

9:00 a.m. Induction Machinery

CP.* Present-Day Techniques of Noise Measurement. *B. G. Watters*, Bolt Beranek and Newman, Inc.

CP.* Techniques for Estimating Sound Levels in Industrial Areas. *R. O. Fehr*, General Electric Company

CP.* The Noise Levels of Some Typical Polyphase Induction Motors. *R. L. Wall*, General Electric Company

CP.* Techniques of Reducing Noise in Machinery with Particular Application to Electric Motors. *B. J. Schweitzer, H. C. Hardy*, Armour Research Foundation of Illinois Institute of Technology

CP.* Hysteresis Torque and Core Loss Variation in Induction Motors. *J. F. H. Douglas, J. Frank*, Marquette University

9:00 a.m. The Author Meets the Publisher

Part I—So You're Thinking of Writing a Book

CP.* Words of Wisdom from a Book Publisher. *J. S. Snyder*, John Wiley and Sons, Inc.

CP.* Comments from an Author. *R. F. Shea*, General Electric Company

Part II—Writing for a Scientific or Technical Journal

CP.* A Publisher Presents Some Ideas. *Gerard Piel*, Scientific American, Inc.

CP.* An Editor's Viewpoint. *W. W. MacDonald*, McGraw Hill Publishing Company

CP.* Comments from an Author. *E. H. Vedder*, Westinghouse Electric Corporation

9:00 a.m. Effect of Low Frequency and Low Voltage on Thermal Plant Capability

54-390. The Effect of Frequency and Voltage. *Richard Holgate*, Philadelphia Electric Company

54-391. Operation at Low Frequency in Great Britain. *F. J. Squire*, British Electricity Authority

54-370. The Effect of Frequency Reduction on Plant Capacity and on System Operation. *H. A. Bauman, G. R. Hahn, C. N. Metcalf*, Consolidated Edison Company of New York, Inc.

54-368. Effect of Reduced Voltage and/or Frequency upon Steam Plant Auxiliaries. *O. D. Butler, C. J. Swenson*, Commonwealth Edison Company

54-320. Forced Outage Rates of High Pressure Steam Turbines and Boilers. *Joint Subcommittee on Application of Probability Methods to Power System Problems*

9:00 a.m. Magnetic Amplifiers

54-325. Techniques for Measuring Cascaded Self-Saturating Magnetic Amplifier Performance. *Henry Kaplan, Gerald Wolff*, Ford Instrument Company

54-392. Magnetic Characteristics Pertinent to the Operation of Cores in Self-Saturating Magnetic Amplifiers. *R. W. Roberts*, Westinghouse Electric Corporation

54-393. Single-Ended Saturable Reactor Circuit with Quiescent Current Compensation. *R. J. Radus*, Westinghouse Electric Corporation.

54-377. Magnetic Amplifier Control of R-J Generators. *G. R. Mohr, Reuben Lee*, Westinghouse Electric Corporation

54-309. Analysis of Magnetic Amplifiers by the Use of Difference Equations. *P. R. Johannessen*, Massachusetts Institute of Technology

2:00 p.m. Air Transportation

54-420. The Nature of Voltage Ripple on D-C Generators. *F. N. Callamore*, Jack and Heintz, Inc.

CP.* Aircraft A-C Generator Electrical Machine Constants As Affected by Design Variations. *R. P. Judkins*, Westinghouse Electric Corporation

CP.* Some Design Criteria for Aircraft A-C Generating Systems. *T. B. Owen*, Hughes Aircraft Company

CP.* Build Up Problems in A-C Generators for Aircraft. *R. M. Fisher, E. F. Hanson*, General Electric Company

2:00 p.m. Rotating Machinery Insulation

54-366. New Performance Standards for Electrical Insulation of Rotating Machines. *Working Group on Evaluation of Insulation for Rotating Machines*

54-373. Insulation Systems for Random Wound Motors Evaluated by Motorette Tests. *T. J. Gair*, General Electric Company

CP.* Comparison of Test Methods for Evaluating Motor Insulation. *R. H. Rech, E. Tepassowski*, A. O. Smith Corporation

CP.* Results of Co-operative Tests on Enameled Wire. *J. F. Dexter*, Dow-Corning Corporation

CP.* Progress Report of Insulation Functional Evaluation Program on Test Bars and Model Windings. *G. L. Moses*, Westinghouse Electric Corporation

2:00 p.m. Load Relief During Power System Emergencies

54-369. Load Shedding Program in the Pacific Northwest. *J. O. Swenson, J. P. Jolliffe*, Bonneville Power Administration

54-345. Load Reduction by Underfrequency Relays During System Emergencies. *W. C. Gerrish*, Houston Lighting and Power Company

54-372. Application and Test of Frequency Relays for Load Shedding. *L. L. Fountain, J. L. Blackburn*, Westinghouse Electric Corporation

54-330. Automatic Digital Computer Solution of Load Flow Studies. *J. M. Henderson*, General Electric Company

2:00 p.m. Management

CP.* Organization and Management of an Atomic Power Station. *Titus LeClair*, Commonwealth Edison Company

CP.* Organization of a Small Company for Complex Engineering Work. *John Logan*, Cambridge Corporation

2:00 p.m. Industrial Control

54-347. Accurate Control of Relative Speed and Cut in a Continuous Process Line. *E. G. Auger, D. L. Pettit*, Square D Company

CP.* Servo Type Speed Regulator. *N. L. Peterson*, Cutler-Hammer, Inc.

CP.* Ambient-Compensated Thermal Overload Relays for Outdoor Control Centers. *R. M. Brokaw*, General Electric Company

CP.* Speed Regulation of Press with Eddy Current Clutch and Brake. *A. E. Lentz, J. W. Fox*, Clark Controller Company

2:00 p.m. Cathodic Protection

CP.* Electrical Grounding and Cathodic Protection at the Fairless Works. *W. E. Coleman, H. G. Prentice*, United States Steel Corporation

CP.* Magnetic Amplifier Control of Cathodic Protection Equipment. *D. R. Werner*, American Telephone and Telegraph Company

—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—Prices of papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Special Publication S-66, eleven papers available only collectively, will be $2.00 per copy. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Committee on Technical Operations ultimately will be published in the bimonthly publications and Transactions.

CP.* Cathodic Protection Circuits. *E. W. Schwarz R. M. Wainwright*, University of Illinois

CP.* Whether Cathodic Protection. *L. M. Flynn*, Illinois Bell Telephone Company

Wednesday, October 13

9:00 a.m. Higher Distribution Voltage for Metropolitan Areas

NOTE: The papers in this session have been published as a part of Special Publication S-66, 11 papers; Price $2.00.

S-66. A New Approach to the Problem of Higher Distribution Voltages. *A. M. DeBellis*, Consolidated Edison Company of New York, Inc.; *S. B. Grisson*, Westinghouse Electric Corporation

S-66. Economics of Various Secondary Voltages for Commercial Areas. *T. C. Duncan, J. P. Neubauer, J. M. Comly*, Consolidated Edison Company of New York, Inc.; *R. F. Lawrence, Miles Maxwell*, Westinghouse Electric Corporation

S-66. Distribution Equipment Used on 265/460 Volt Networks and Its Operating Features. *L. Brieger, C. P. Xenis, A. J. Bitros, J. DeLallis*, Consolidated Edison Company of New York, Inc.

S-66. Secondary Network Equipment for 250 to 600 Volt Systems. *R. L. Schmidt, E. W. Stahr*, Westinghouse Electric Corporation

S-66. Future Utilization Voltages. *L. G. Smith*, Consolidated Gas, Electric Light and Power Company of Baltimore

9:00 a.m. Air Transportation

54-327. Overvoltage Detection in Single and Multigenerator Aircraft A-C Systems. *W. M. Tucker, M. Trbovich*, U. S. Naval Research Laboratory

CP.* Protection of Aircraft Parallel A-C Systems Against Excitation Failures. *H. H. Britton, S. C. Caldwell, A. J. Wood*, General Electric Company

54-357. A Weight Analysis of Modern Aircraft Electric Systems. *H. L. Garberino, A. K. Hawker, J. A. Granath*, Armour Research Foundation of Illinois Institute of Technology

CP.* British Aircraft Electrical Engineering Practice. *H. Zeffert.*

9:00 a.m. Nucleonics

CP.* Nuclear Reactors for the Production of Power. *Stuart McLain*, Argonne National Laboratories

CP.* Reactor Control. *Joseph Hurwe*, Argonne National Laboratories

CP.* Instruments for Radiation Measurement. *John Rose, L. D. Marinelli*, Argonne National Laboratories

CP.* Nondestructive Testing. *Warren McGonnagle*, Argonne National Laboratories

CP.* New Atomic Energy Act. *Stuart MacMackin*, General Electric Company

54-524. Measurements of Materials with High Dielectric Constant and Conductivity at Ultra-High Frequencies. *H. P. Schaus, Kun Li*, University of Pennsylvania

9:00 a.m. Feedback Control Systems

54-521. Jitter in Instrument Servos. *R. L. Hennon*, Goodyear Aircraft Corporation

54-522. Evaluating the Effect of Non-Linearity in a 2-Phase Servo Motor. *W. A. Stein* and *G. J. Thaler*, U. S. Naval Postgraduate School

54-529. A Magnetic Tape Memory for D-C Positional Servomechanisms. *J. F. DeBarber*, The Pennsylvania State University

CP. Stability of Nonlinear Feedback Control Systems and Induction Motors with Series Capacitors.** *J. F. Koenig*, National Bureau of Standards

9:00 a.m. Land Transportation

54-530. Diesel-Electric Locomotive Wheel Slipping—Causes, Effects and Methods of Control. *R. I. Fort*, Illinois Central Railroad

54-538. Maintenance Testing of Insulation Resistance on Diesel-Electric Locomotives. *W. E. Kelley*, Pennsylvania Railroad Company

54-544. Operating Experience in Diesel-Electric Locomotives. Results in Design Changes. *L. E. Lagg*, Chicago and Northwestern Railroad

54-582. Gearing for Diesel-Electric Locomotives. *G. T. Bean*, International General Electric Company

54-543. The Toronto Subway. *J. G. Inglis*, Toronto Transit Commission

9:00 a.m. Visual Output Devices: Printers and Plotters

CP.* Servomechanical Devices as Aids to Analysis, Data Handling, and Control. *F. L. Moseley*, F. L. Moseley Company

CP.* An X-Y Recording System for Computers. *D. L. Pickens, B. L. Waddell*, Librascope, Inc.

CP.* History of X-Y Recorders. *J. D. Kennedy*, Electronic Associates

CP.* Ferromagnetography. *J. P. Hanna*, General Electric Company

9:00 a.m. Rotating Machinery Insulation

54-565. The Motorette as a Tool for the Development of Improved Insulation Systems. *W. B. Penn*, General Electric Company

CP.* The Evaluation of Modified Silicone Insulation Systems in Motors. *Jack McDonald*, Westinghouse Electric Corporation

CP.* Insulation Systems Evaluated Using Motorettes and Formettes. *Lanier Greer*, Reliance Electric and Engineering Company

CP.* A Statistical Method for Predicting Insulation Life in Motors from Experimental Data. *W. H. Horton*, Westinghouse Electric Corporation

CP.* Proposed Test Procedure for Evaluation Systems of Insulation for High Voltage Generators. *G. L. Moses*, Westinghouse Electric Corporation

2:00 p.m. Higher Distribution Voltage for Metropolitan Areas

NOTE: The papers in this session have been published as a part of Special Publication S-58, 11 papers; price $2.00.

S-66. The Relative Feasibility of 460-Volt or 208-Volt Service in Commercial Buildings. *H. G. Barnett, R. A. Zimmerman, H. E. Lokay*, Westinghouse Electric Corporation

S-66. Progress in Power System Engineering for Commercial Buildings. *H. D. Kurt, Donald Beeman*, General Electric Company

S-65. Service Voltage Spread and Its Effect on Utilization Equipment. *H. G. Barnett, F. R. Lawrence*, Westinghouse Electric Corporation

S-65. 480Y/277 Volt Power System in Telephone Building at Menands, New York. *D. S. Brereton*, General Electric Company; *H. J. Donnelly*, New York Telephone Company

S-66. The Advantages of 240/416 Volts as a Standard Secondary Voltage. *J. B. Hodson*, Allis-Chalmers Manufacturing Company

2:00 p.m. Communication Switching Systems

54-502. Interoffice Trunking and Signalling. *F. H. Nolde*, Rural Electrification Administration

54-503. Some Recent Advances in the Economy of Routing Calls in Nationwide Toll Dialing. *Imre Molnar*, Automatic Electric Company

CP.* Nationwide Dialing. *D. W. Harbint*, American Telephone and Telegraph Company

54-547. Automatic Percussion Welding. *A. L. Quinlan*, Western Electric Company

2:00 p.m. Air Transportation

54-559. Calculations on Voltage Unbalance for 3-Phase Synchronous Systems. *B. J. Wilson, W. K. Gardner*, U. S. Naval Research Laboratory

54-574. Experimental Determination of 400-Cycle Impedance of Wire in Aircraft Power Distribution Circuits. *J. D. Andrew*, Douglas Aircraft Company, Inc.

CP.* Comparison of Solid and Split Bus Two Generator A-C Systems. *S. C. Caldwell, G. A. Phillips*, General Electric Company

CP.* Evaluation of Selenium Rectifiers and Capacitors for Use in Aircraft. *R. A. Yeranee, A. A. Balafas*

2:00 p.m. Power Generation

54-504. Underexcited Reactive Ampere Limit for Modern Amplidyne Voltage Regulator. *A. S. Rubenstein, M. Temashek*, General Electric Company

54-384. Synchronous Condenser Operation with Negative Field Current. *R. R. McClymont, P. L. Dandeno*, Hydro Electric Power Commision of Ontario

54-505. Motor-Driven Excited Sets for Power Stations. *J. B. Tice, M. Temashek*, General Electric Company

54-506. The Gas Turbine Today. *C. F. Kottcamp*, Gulf Oil Corporation. Re-presented for discussion

54-507. The Success of the Steam Boiler. *G. V. Williamson*, Union Electric Company of Missouri. Re-presented for discussion

54-508. Turbine Generators—Present and Future. *E. H. Krieg*, Stone and Webster Engineering Corporation. Re-presented for discussion

2:00 p.m. Visual Output Devices: Displays and Applications

CP.* The Charactron as a Digital Computer Read-Out. *J. T. McNaney*, Convair Division of General Dynamics Corporation

CP.* A New Technique of Binary Addition. *W. J. Schart*, Convair Division of General Dynamics Corporation

CP.* Automatic Data Transfer and Display Boards. *G. E. Fominow*, Civil Aeronautics Administration

CP.* Simultaneous Aircraft Position and Identification Display. *J. T. McNaney*, Convair Division of General Dynamics Corporation

2:00 p.m. Feedback Control Systems

54-371. The Maximum Response Ratio of Linear Systems. *P. E. Pfeiffer*, Rice Institute

54-519. Phase-Plane Analysis of Automatic Control Systems with Nonlinear Gain Elements. *R. E. Kalman*, E. I. du Pont de Nemours and Company

CP. A Simple Method for Calculating the Time Response of a System to an Arbitrary Input.** *G. A. Biernson*, Massachusetts Institute of Technology

54-523. Additions to z-Transformation Theory for Sampled-Data Systems. *G. V. Lago*, University of Missouri

Thursday, October 14

9:00 a.m. Air Transportation

CP.* Performance Characteristics of a Constant Speed Differential Hydraulic Transmission System. *R. S. Conrad*, Chance Vought Aircraft

CP.* Controlled Speed A-C Generator Drive Selection for the Light Weight Combat Airplane. *R. E. Thorn, T. E. Abraham.*

CP.* Accessory Design Problems. *J. E. Wolf*, Marquardt Aircraft Company

CP.* Air Turbine Drives—Performance and Limitations. *L. Royce*, Stratos Division of Fairchild Engine and Airplane Corporation

9:00 a.m. Relays and Transmission and Distribution

54-532. The Probability of Coincident Primary Feeder Outages in Secondary Networks. *D. N. Rapp*, Westinghouse Electric Corporation

54-563. Co-ordination of Construction and Protection of Distribution Circuits—5 Kv Class Based on Operating Data for Years 1949–51. *Joint AIEE-REI Working Group*

CP.* Fundamentals of Fuse-Breaker Co-ordination. *L. D. Cronin, Chase Hutchinson, D. M. MacGregor*, Ebasco Services, Inc.

CP.* Co-ordination of Sectionalizing Devices for Primary Feeder Protection. *H. B. Thacker*, Westinghouse Electric Corporation

CP.* Eight Years Experience with Oil Circuit Reclosures in Substations. *A. C. Fagerlund, G. D. Stevens*, Consumers Power Company

9:00 a.m. Transformers

54-524. Auto Transformers for Power Systems. *O. T. Fury*, Wagner Electric Corporation

54-395. A Proposed New Standard Control Scheme for Paralleling Transformers with Under-Load Tap Changers. *J. Cesar*, Hydro Electric Power Commision of Ontario

54-579. Electrostatic Voltage Distribution and Transfer in 3-Winding Transformers. *P. A. Abetti*, General Electric Company

54-580. Surge Transfer in 3-Winding Transformers. *P. A. Abetti*, General Electric Company; *H. F. Davis*, Massachusetts Institute of Technology

9:00 a.m. International Communications

CP.* A TransAtlantic Telephone Cable. *M. J. Kelly, G. W. Gilman*, Bell Telephone Laboratories, Inc., *Sir W. Gordon Radley, R. J. Halsey*, Post Office of the United Kingdom

54-424. Rural Automatization in the Swedish Telephone System. *Bertil Bjurel*, presented by Håkon Sterky, Direction Generale des Telecommunications de Suede

9:00 a.m. Direct Current Machinery

54-522. An Improved Wide-Range Adjustable-Speed Drive. *A. G. Conrad, A. R. Perrins, R. R. Shank*, Yale University

54-567. A Method of Finding Equaliser Section for D-C Armature Winding. *T. C. Tsao*, Ebasco International Corporation; *N. F. Tsang*, University of Arkansas

54-319. Equations Depicting the Operation of the D-C Motor. *R. W. Ahlquist*, University of Detroit

CP.* Measurement of Dynamic Parameters of D-C Dynamos. *L. D. Harris, R. E. Stephenson*, University of Utah

54-551. Air Humidity and Brush Contact Drop: The Effect of Water Vapor, Sulfur Dioxide, and Hydrogen Sulfide. *H. M. Elsey, L. E. Moberly, J. L. Johnson*, Westinghouse Electric Corporation. Re-presented for discussion

9:00 a.m. Basic Sciences

54-361. A Comparison of Metals and Ferrites for High-Speed Pulse Operation. *D. R. Brown, D. A. Buck, N. Menyuk*, Massachusetts Institute of Technology. Re-presented for discussion

54-509. The Behavior of Thallium in Counter Electrode Solders for Selenium Rectifiers. *W. B. Roberts*, Sarkes-Tarzian, Inc.; *A. D. Arnaut*, Wall Colmonoy Corporation; *H. Bondar*, Sylvania Electric Products

54-510. Characteristics of the High Current Argon Arc with Various Electrode Materials. *J. W. Dominianni*, Allis-Chalmers Manufacturing Company; *T. B. Jones*, The Johns Hopkins University

54-511. The Measurement of Electrostatic Potential Due to Net Ion Space Charge in Air. *J. S. Carroll, S. B. Hammond*, Stanford University

54-512. Harmonic Analysis for Nonlinear Characteristics. *L. J. Lewis*, University of Washington

2:00 p.m. Air Transportation

CP.* Use of Analogues in Jet Engine Control Development. *S. Crowell, R. Poston, C. Thompson*

CP.* An Airborne Transceiver. *K. E. Vaughn*

CP.* A Simplified Omni-Range System for Terminal Navigation (TVOR). *D. O. McCoy.*

54-358. Aircraft Tachometer Indicator—An Analysis of Design Factors Affecting Starting Performance. *L. T. Akeley*, General Electric Company

2:00 p.m. Transmission and Distribution

54-337. Economics of Switched Shunt Capacitors and Synchronous Condenser Kilovar Supply for Transmission Systems. *P. G. Brown, G. W. Otte, L. E. Salins, V. C. Talley*, General Electric Company

54-385. An Evaluation of Power Factor Correction on a System Basis. *H. R. Tomlinson, R. O. Bigelow*, New England Power Service Company

54-331. Transient Stability Studies—I. Synchronous and Induction Machines. *D. F. Shanklin, C. M. Murphy, R. W. Long, E. L. Harder*, Westinghouse Electric Corporation

54-501. Practical Application of Sag and Tension Calculations to Transmission Line Design. *J. Lummis, H. D. Fischer, Jr.*, Southern California Edison Company

54-348. Aircraft Windshields Heated by Means of Transparent Conductive Films. *J. W. Ward*, Boeing Airplane Company. Re-presented for discussion.

2:00 p.m. High-Fidelity and Magnetic Recording

CP.* A New High-Fidelity High-Powered Amplifier and Speaker Reproducing System. *F. H. McIntosh*, Consulting Engineer

CP.* General Problems of Standardization in the Electronic Industries with Reference to the Definition of High Fidelity. *F. H. Slaymaker*, Stromberg-Carlson Company

54-383. A Survey of Magnetic Recording. *S. J. Begun*, Clevite-Brush Development Company

2:00 p.m. Direct Current Machinery

54-326. A New Method of Investigating Commutation as Applied to Automotive Generators. *E. I. Shobert, II, J. E. Diehl*, Stackpole Carbon Company

CP.* Reconditioning of Electrical Equipment which Has Been Submerged in Salt Water. *W. H. Fifer*, Bureau of Ships, U. S. Navy

CP.* Plant Maintenance for Brushes and Commutators. *L. D. Cook*, Commonwealth Edison Company

CP.* Field Problems in D-C Machinery. *H. Q. Griffith*, Belyea Company, Inc.

2:00 p.m. Relays and Transformers

54-396. Detection of Corona in Oil at Very High Voltages. *T. W. Liao, J. S. Kreitz*, General Electric Company

54-397. The Effect of Reclosing Practice on Short Circuit Thermal Limits of Transformers. *J. E. Clem*, Consulting Engineer

54-398. Operating Experience with 230-Kv Automatic Reclosing on Bonneville Power Administration System. *D. A. Gillies*, Bonneville Power Administration

54-518. Bibliography on Transformer Noise. *AIEE Transformer Committee, Subcommittee on Subject #30, Working Group #1*

Friday, October 15

9:00 a.m. Air Transportation

CP.* Aircraft Equipment Electrical Insulation Problems. *L. B. Kilmer, J. P. Dallas*, Hughes Tool Company

54-422. Environmental Testing of Small Electronic Components at High Sound Intensities. *F. Mintz, M. B. Leone*, Armour Research Foundation of Illinois Institute of Technology

54-423. Development of Large-Ratio Release Circuit-Breaker Mechanism. *J. A. Scarselli, R. Steiner*, U. S. Naval Air Development Center

54-352. Comments on Aircraft Switch Testing. *T. R. Studtmann, J. P. Dallas*, Los Angeles, Calif.

54-353. Reliability Improvement—A Plan to Achieve and Measure Reliability of Aircraft Equipment. *J. E. Luckman*, U. S. Naval Air Development Center

9:00 a.m. Insulated Conductors

CP.* A Classified Bibliography for Insulated Conductors—A Committee Report. *A. S. Brookes*, Chairman, Standards and Publications Subcommittee

54-399. Moisture Studies on Ozone Resisting and Type RHRW Rubber Insulations. *E. C. DeBorne, C. A. Anderson*, The Detroit Edison Company

CP.* The Effects of High Energy Gamma Radiation on Dielectric Solids. *P. H. Klein, C. Mannal*, General Electric Company

CP.* X-Ray Cable—Its Design for Long Service. *L. A. Dunn*, American Steel and Wire Company

9:00 a.m. Switchgear

54-342. Adaptation of a Conventional Oil Circuit Breaker to Capacitance Switching. *E. J. Simmons*, Long Island Lighting Company; *V. A. Treat*, Pacific Electric Manufacturing Corporation

54-341. Maintenance Testing of Oil Circuit Recloser Insulation with High Voltage D-C. *R. W. Bothe, L. C. Westphal*, Line Material Company

54-340. A New 69-Kv Oil Circuit Breaker for High Interrupting Duty. *V. E. Phillips, K. G. Darrow*, General Electric Company

CP.* The Design of Industrial Distribution Systems: An Epitomization of Available Data—Part II. *T. J. Higgins*, University of Wisconsin

9:00 a.m. Color Television and International Broadcasting

54-334. Differential Phase and Gain Measurements in Color Television Systems. *H. P. Kelly*, Bell Telephone Laboratories, Inc.

CP.* Recording Color Television Programs. *E. D. Goodale*, National Broadcasting Company

CP.* The Engineering Development of the Voice of America. *E. T. Martin, Julius Rosi, George Jacobs*, U. S. Information Service

CP.* Very-High-Powered Long-Wave Broadcasting Station. *C. E. Smith*, Carl E. Smith Consulting Radio Engineers; *J. R. Hall, J. O. Weldon*, Continental Electronics Manufacturing Company

9:00 a.m. Metal Industry

CP.* A New Method of Calculating D-C Dynamic Braking for Wound Rotor Motors. *B. H. Carlisle*, Clark Controller Company

54-348. A-C Power System at the Fairless Works. *S. S. Watkins*, Gibbs and Hill, Inc.; *W. A. Derr, L. L. Fountain, R. B. Squires*, Westinghouse Electric Corporation

CP.* Modern Tinplate Annealing. *John Soyring*, U. S. Steel Corporation; *A. C. Parsons*, General Electric Company

CP.* Modern Controls for New 4-Stand Cold Mill at Youngstown Sheet and Tube Co. *C. E. Homer*, Youngstown Sheet and Tube Company; *R. E. Manks*, General Electric Company

9:00 a.m. Electric Circuit Theory

54-513. The Transmission-Matrix of N Alike Cascaded Networks. *Leo Storch*, Hughes Aircraft Company

54-514. Acceleration Plane Method for Analysis of a Circuit with Nonlinear Inductance and Nonlinear Capacitance. *Y. H. Ku*, Moore School of Electrical Engineering

54-515. Analysis of Nonlinear Coupled Circuits. *Y. H. Ku*, Moore School of Electrical Engineering

54-516. A Rectifier Algebra. *D. H. Schaefer*, U. S. Naval Research Laboratory

54-394. A Symbolic Method for Synthesis of 2-Terminal Switching Circuits. *D. Zobel, W. P. Caywood*, Carnegie Institute of Technology

2:00 p.m. Insulated Conductors

54-338. Economics and Comparison of Reliability of Leaded and Non-Leaded Secondary Distribution Systems. *E. L. Leinback*, The Detroit Edison Company; *C. P. Xenis*, Consolidated Edison Company of New York.

54-378. A Progress Report on Performance of Secondary Network Cables. *E. C. DeBorne, F. M. Hull, R. H. Hiester*, The Detroit Edison Company

54-335. High Pressure Self-Contained Gas-Filled Cable Installation. *G. B. Shanklin*, General Electric

2:00 p.m. Protective Devices

54-360. Grounding of Sub-Transmission Systems. *O. D. Bruser, I. B. Johnson, S. V. Lyon*, General Electric

54-400. Protective Spark Gaps with Radio-Active Substances. *D. R. Hardy*, The University of Manchester

CP.* The Control of High-Voltage Impulse Generators. *D. R. Hardy, T. E. Broadbent*, The University of Manchester

2:00 p.m. Mining Industry

CP.* Modern Electric Power Shovels. *J. F. Weis*, Marion Power Shovel Company

CP.* Magnetic Amplifier Regulator Control for Mine Hoist. *R. E. Peterson*, Westinghouse Electric Corp.

CP.* Substitutes for Frame Grounding of Mining Machinery. *E. J. Gleim*, U. S. Bureau of Mines

CP.* Special Motor Applications for Underground Mining Machinery. *C. C. Boesenetter, R. M. Buckeridge*, Goodman Manufacturing Company

2:00 p.m. Radio and Wire Communications

A Single Presentation will be made of the first six papers:

54-401. A New Multichannel Teletype Terminal for Use on Long Range H-F Radio Systems. *A. Mack, R. H. Levine*, U. S. Signal Corps Engineering Laboratories

54-402. Telegraph Terminal AN/FGC-29 Equipment Features. *F. H. Cusack*, Western Union

54-403. Telegraph Terminal AN/FGC-29 Circuit Design Aspects. *J. E. Boughtwood*, Western Union

54-404. Considerations for a New Military Radio Relay System. *M. L. Ribs, S. P. Brown*, U. S. Signal Corps Engineering Laboratories

54-405. A New UHF Multichannel Military Radio Relay System. *J. G. Nordahl*, Bell Telephone Laboratories, Inc.

54-406. Equipment and Mechanical Features of the AN/TRC-24 Radio Set. *V. I. Cruser*, Bell Telephone Laboratories, Inc.

54-407. A Private Microwave Radio System for Power Company Use. *D. F. Hasen*, Illinois Power Company; *J. W. Dauzer, G. S. Zilis*, Illinois Bell Telephone

A Single Presentation will be made of the following five papers:

54-408. Considerations for Development of New Military Carrier Telephone Systems. *R. S. Boykin, J. H. Johnson, S. D. Bedrosian*, U. S. Signal Corps Engineering Laboratories

54-409. A New Cable Design for Military Carrier Telephone Systems. *H. F. X. Kingsley*, U. S. Signal Corps Engineering Laboratories

54-386. New Military Carrier Telephone Systems. *G. H. Huber, W. R. Miller, C. W. Schramm*, Bell Telephone Laboratories, Inc.

54-410. New Military Carrier Telephone Systems Equipment Features. *J. P. Hofmann*, Bell Telephone Laboratories, Inc.

54-411. Simplified Transmission Engineering in Exchange Cable Plant Design. *L. B. Began, K. D. Young*, American Telephone and Telegraph Company

2:00 p.m. Single Phase and Fractional HP Machinery

54-356. Space Harmonics Generated by Concentric Windings. *A. J. Berman, G. Farmanfarma, R. Schisinger*, University of California

54-328. Iron Loss in Universal Motors. *W. E. Wier*, Westinghouse Electric Corporation

54-412. Permanent Magnet Excited Synchronous Motors. *F. W. Merrill*, General Electric Company

54-413. Unbalanced Magnetic Pull in Induction Motors with Eccentric Rotor. *A. Case*, Westinghouse

(Continued from page 940)

THEATER AND SPORTING EVENTS

Tickets for all theatrical and sporting events will be available at the ticket desk throughout the entire week of the convention. Arrangements have been made with one of the local ticket agencies so that satisfactory seats will be available. For typical $5.00 tickets the agency fee is $2.00.

TELEVISION AND RADIO

Tickets for those television and radio programs which are showing during the week of the convention will be available at the desk at no charge. These television shows are "Breakfast Club" with Don McNeil and "Welcome Travelers" with Tommy Bartlett.

HOTEL RESERVATIONS

Hotel room reservation requests should be sent to Convention Department, Morrison Hotel, Madison and Clark Streets, Chicago 2, Ill., or to the hotel of your choice. AIEE should be mentioned in the request, and a copy sent to G. L. Welch, Hotel Arrangements Committee, c/o Westinghouse Electric Corporation, Merchandise Mart, Chicago 54, Ill.

Accommodations at the Morrison Hotel are as follows:

Single Room (one person)	$ 5.50 to $12.00
Double Room-Double Bed (2 persons)	9.00 to 16.00
Double Room-Twin Beds (2 persons)	11.50 to 16.00
Suites—Parlor, Bedroom (Double Bed)	18.00 and 22.00
Suites—Parlor, Bedroom (Twin Beds)	27.00 to 37.00

INSPECTION TRIPS

Aliens should give advance notice of plans to make inspection trips. Some of these trips will require a minimum of 24 hours to make arrangements for aliens to visit plants. They should state their names, nationalities, business connections, and the nature of their business in this country.

Registration for the following inspection trips will be limited. These include:

Hawthorne Plant, Western Electric Company
Delta-Star Division of H. K. Porter Company
Motorola, Inc.
Ridgeland Station
Republic Steel Company
University of Chicago Institutes for Basic Research
Rauland Corporation

For full descriptions of these trips see the September issue of *Electrical Engineering* (*pp. 828–9*).

REGISTRATION

Members can simplify registration procedures by returning the registration card promptly. This will save time in completing registration details upon arrival at the hotel. The registration desk in the Morrison Hotel will be open Sunday afternoon, October 10, and will be open daily thereafter during convention hours. The registration fee will be $3.00 for members and $5.00 for nonmembers. No fee will be required of enrolled students and immediate families of members.

COMMITTEE

The 1954 Fall Meeting Committee Members:

General Chairman, Francis A. Cox; *Vice-Chairman*, Frank D. Troxel; *Secretary*, Howard R. Stevens; *Treasurer*, Marvin V. Maxwell; *Hotel Arrangements*, William M. Ballenger; *Finance and Budget*, John C. Woods; *Technical Program*, Arthur B. Bronwell; *Registration*, Elmer G. Norell; *Trips—Transportation*, Merlin J. Adams; *Dinner-Dance*, Edwin R. Whitehead; *Smoker*, John Romano; *Entertainment*, L. E. Randall; *Sale of Papers*, Leonard R. Janes; *Ladies Activities*, Mrs. R. R. O'Conner; *Hospitality*, Rudolph C. Erickson; *Chicago Section Representative, General Session Program*, Nathan Cohn; *Publicity*, Ed Allen.

ECPD Will Hold Annual Meeting Late This Month in Cincinnati

The 22nd Annual Meeting of ECPD (Engineers' Council for Professional Development) will be held in Cincinnati, Ohio, October 28–29, 1954. Cincinnati is an appropriate location, for it was there the first pilot program of "The First Five Years of Professional Development" was inaugurated in co-operation with the University of Cincinnati and a number of local industries. Naturally, the program will be devoted to professional development, and prominent engineers, executives, and educators will discuss the various aspects. Meeting headquarters will be at the Hotel Alms.

Several years ago ECPD's Training Committee recognized that the first five years of professional development after leaving college represented the most critical period of the young engineer's career. To meet this need, the committee developed a 6-point program: 1. Orientation and training in industry; 2. Continued education; 3. Integration into the community; 4. Profesional registration; 5. Self-appraisal; 6. Selected reading.

The program in Cincinnati has been so successful that steps are being taken to initiate similar programs in other large industrial centers: Detroit, Minneapolis, St. Paul, Oklahoma City, Atlanta, Houston, St. Louis, and Hamilton, Ontario, Canada. Professor Cornelius Wandmacher, who is chairman of ECPD's Training Committee, is in charge of the Cincinnati program.

Council business and committee meetings will comprise the first day's program. The training program will be dacussed on the second day with introductory remarks on "A Community Project in Professional Development" by A. C. Monteith, vice-president in charge of engineering, Westinghouse Electric Corporation, and E. S. Fields, vice-president and general manager, Cincinnati Gas and Electric Company. Mr. Monteith was instrumental in developing the 6-point program and made a 160-page report when chairman of the ECPD Training Committee.

A panel presentation of "Professional Development Activities in Cincinnati" will also be held on October 29 with speakers representing the points of view of industry, the engineering societies, and the university.

Luncheon speaker for the same day will be Frank J. Curtis, vice-president and director of the Monsanto Chemical Company.

In the afternoon, the community aspects of the "First Five Years Program" in the large industrial centers of Houston, Minneapolis, St. Paul, Atlanta, Detroit, Hamilton, Oklahoma City, and Hamilton, Ontario, Canada, will be discussed.

As a climax James H. Taylor, assistant director for manpower, Office of Defense Mobilization, will be the featured speaker at the Friday evening dinner on the subject, "The National Manpower Outlook from the Point of View of the Profession." Mr. Taylor is currently on loan to the government from the Proctor & Gamble Company, where he is director of industrial relations. From a wealth of industrial and governmental experience, he will relate the importance of the training program to the manpower situation and national security.

Tentative ECPD Program

Thursday, October 28

9:00 a.m. Closed Council Meeting
12:30 p.m. Luncheon
2:00 p.m. Open Committee Meetings
5:30 p.m. Open Council Meeting
6:00 p.m. Dinner
8:00 p.m. New Executive Committee and new Committee Organization meetings

Friday, October 29 Training Committee Program

9:30 a.m. A Community Project in Professional Development.
Introductory Remarks: *A. C. Monteith*, Westinghouse Electric Corporation; and *E. S. Fields*, Cincinnati Gas and Electric Company.

10:00 a.m. Professional Development Activities in Cincinnati (A Panel Presentation).
For Industry: *D. F. Pratt*, Cincinnati Milling Machine Company; *E. G. Huck*, Cincinnati Gas and Electric Company. **For Engineering Societies:** *S. F. Storrs*, vice-president, Engineering Society of Cincinnati; *Raphael Kaiser*, consulting chemical engineer. **For University:** *Hoke Greene*, University of Cincinnati; *William Middendorf*, University of Cincinnati.

12:00 p.m. Luncheon
Speaker: *F. J. Curtis*, Monsanto Chemical Company

2:00 p.m. Community Aspects of the "First Five Years Program"

In Houston: *J. J. McKetta*, Gulf Publishing Company

In Minneapolis, St. Paul: *H. M. Hill*, Northern State Power Company

In Atlanta: Messrs. *R. L. Sweigert*, Georgia Tech, *E. W. O'Brien*, W. R. C. Smith Publishing Company, and *J. A. Higgs*, Massey Concrete Products Company

In Detroit: *C. J. Freund*, University of Detroit

In Oklahoma City: Messrs. *R. F. Danner*, Oklahoma Gas and Electric Company, and *D. R. McKeithen*, Phillips Petroleum Company

In Hamilton, Ontario, Canada: *G. L. Schneider*, consulting engineer

7:00 p.m. Dinner

The National Manpower Outlook From the Point of View of the Professions. *James H. Taylor*, assistant director for manpower, Office of Defense Mobilization

Seventh Annual Conference on Electrical Techniques in Medicine and Biology

The Seventh Annual Conference on Electrical Techniques in Medicine and Biology will be held at the Morrison Hotel, Chicago, Ill., November 10th, 11th, and 12th under the sponsorship of the American Institute of Electrical Engineers, Institute of Radio Engineers and Instrument Society of America.

Three sessions devoted to technical papers are scheduled. The first one on Wednesday morning will have five papers devoted to circulation and cardiology and in the afternoon electrical properties of biological materials will be considered. On Thursday afternoon five papers on X-rays and instrumentation will be given.

DINNER MEETING

A dinner and evening meeting are also scheduled for November 10. Guest speaker will be Dr. T. E. Allibone, director of research of the Associated Electrical Industries of Great Britain. Dr. Allibone is a fellow of the Royal Society and is known for his work in fields pertinent to the conference.

LABORATORY FIELD TRIPS

Argonne Cancer Research Hospital, Thursday morning. Argonne National Laboratory, Friday morning. Both these installations, operated by the University of Chicago for the U. S. Atomic Energy Commission, are engaged in studies of the effects of radiation on living systems.

The visit to Argonne Cancer Hospital on the 11th will include inspection of the 50 mev microwave linear accelerator, the cobalt-60 rotational therapy unit, the thulium diagnostic unit, etc.

Transportation to and from Argonne National Laboratory will be available and arrangements can be made at the conference registration desk. Visitors to the laboratory are asked to register for the tour before 3:00 p.m. of November 11. Maps and directions will be available for those having their own transportation. The visit will be planned to permit departure from Chicago by late afternoon train or plane.

Citizens of countries other than the U.S. must give three weeks notice through the conference chairman so that admission to the laboratory may be arranged.
(Conference Chairman E. D. Trout, 4855 Electric Avenue, Milwaukee 1, Wis.)

Wednesday, November 10

Morning. Session I. Circulation and Cardiology

Dr. Samuel A. Talbot, presiding

Normalisation of Vector EKG Axes. *Dr Otto Schmitt*, University of Minnesota

Computer Technics in Rapid Determination of Certain EKG Functions. *Dr. Stanley Briller*, Bellevue Hospital

Synthesis of Electrocardiograph Leads. *Dr. Richard McFee*, Bell Telephone Laboratories; *Dr. Franklin Johnston*, University of Michigan Medical School

Determination of the Electrical Center of Ventricular Depolarization in the Human Heart. *Dr. Ernest Frank*, Moore School of Electrical Engineering, University of Pennsylvania

Heart Cell Potential. *Dr. E. E. Suckling*, New York State University

Wednesday, November 10

Afternoon. Session II. Electrical Properties of Biological Materials

Dr. Otto Schmitt, presiding

The Electrical Impedance of a Human Body Segment as Related to Impedance Plethysomography. *Dr. Paul Albro*, Hanings Instrument Company

Electro-ionics of Nerve Action. *Dr. Kenneth S. Cole*, Naval Medical Research Institute

The Application of the Electric Impedance Method in the Study of the Normal and Hemolysed Red Blood Cell. *Dr. Hugo Fricke*, Walter B. James Laboratory for Biophysics

Capacity of Erythrocyte Ghose Membrane Measured over a Wide Frequency Range. *Herman P. Schwan, E. L. Carstensen*, and *K. Li*, Moore School of Electrical Engineering, University of Pennsylvania

Evening

Guest Speaker: Dr. T. E. Allibone, Associated Electrical Industries of Great Britain.

Thursday, November 11

Afternoon. Session III. X-Rays and Instrumentation

Spectral Phonocardiography. *Dr. G. N. Webb*, Johns Hopkins Hospital

New Developments in the Electronic Fluoroscope of the Television Type. *Ralph Sturm, Dr. Russell Morgan*, Johns Hopkins Hospital

Effect of X-Rays on Erythrocytes. *Dr. Otto Blish*, University of British Columbia, Vancouver, Canada

Xerography. *Dr. John Roach*, Albany Medical School

Progress in X-Ray Movies. *E. L. Webb*, Westinghouse Electric Corp.

Middle-Eastern District Meeting
October 5–7, 1954

Registration fees are $2.00 for members and $3.00 for nonmembers instead of the $3.00 and $5.00 fees erroneously stated in the mailed announcement and the September issue of *Electrical Engineering*, page 822. No fees will be charged to students or families of members.

EMC-SMC Reports Improvement in Campus Recruitment Practices

As a service to all concerned in engineering recruitment on college campuses, the EMC (Engineering Manpower Commission of Engineers Joint Council) asked the deans of engineering early this year for comment on the present state of recruiting practices. Response to the request was outstanding and, after analysis, productive of an encouraging conclusion. Here is the report published by both EMC and SMC (Scientific Manpower Commission): There has been a marked improvement in recruiting practices on campuses. The overwhelming verdict of the deans of engineering was that the situation is excellent from the student's as well as their own point of view and, as far as they can tell, from the recruiters' viewpoint.

However, there were some critical comments. But, the overall general conclusion must be drawn after a perusal of the entire correspondence. This general conclusion assumes even greater significance when the terrific competition for engineering graduates that has existed since 1950 is considered. Approximately 90 letters were received from deans of engineering or directors of placement on engineering campuses. About 60 of these letters contained favorable comment.

In its letter of inquiry, EMC said it had heard, from various sources, that undue emphasis was being placed on economic security in the initial approach to engineering graduates. Comment from the deans on this point ranged from the statement that these young men were well-advised to be interested in economic security, to that which cited the utter ridiculousness of this on the part of young men. The important point was, however, and there was practically unanimity on this, that where this occurred it was almost always the result of inquiry or pressure by students.

It would, of course, be amiss to attempt any summary of results of this study that did not include a summary of criticisms appearing most frequently in those replies that were, in any degree, derogatory. The following critical comment is provided for the benefit of all concerned. It might be useful for companies to use the following as a partial check list of their activities to determine what improvement, if any, can be made in their practices:

Some recruiters attempt to short-circuit the placement office, thereby upsetting careful arrangements that have been made to avoid company congestion on the campus.

Some recruiters provide misleadingly optimistic information to students regarding their relation to Selective Service after employment in their company.

The time required by some recruiters for their campus activity is more than can be given on a fair or proportional basis by the students and by campus officials.

Some recruiters do not keep time schedules.

Application forms, especially initial ones, are entirely too long, requiring too much time for completion.

Too much of the time spent with the students is consumed by descriptions of the company rather than discussions of qualifications and other more pertinent matters.

Certain recruiters pressure students to commit themselves before they have had an opportunity to analyse the situation thoroughly and to make a decision based on merit and their own desires.

Some recruiters do not have a sufficiently clear idea of their companies' needs.

Some recruiters obviously have not read orientation material forwarded to the company by the school and, as a result, cause confusion and time loss.

A few companies, through the use of alumni, circumvent the entire campus recruiting system.

Too many of the recruiters are per-

sonnel men completely familiar with their company but quite unfamiliar with details of engineering work, a subject students almost always want to discuss. There is, however, a noticeable trend to include active engineers in recruiting parties.

Several deans expressed the desire to see created a systematic means of exchanging information between colleges and companies on the progress graduates make with their employers. They added that unless colleges are kept advised or keep themselves advised of the graduates' performance on the job, it is extremely difficult to improve and develop the engineering curricula.

Improvement in recruiting practices revealed by this study is an accomplishment growing out of cooperation of industrial representatives and the engineering colleges in observing the ASEE Code. Copies of the Code may be obtained from A. B. Bronwell, Secretary of ASEE, Northwestern University, Evanston, Illinois.

AIEE Textile Conference to Be Held Next Month

AIEE's Textile Conference will be held November 4 and 5 (Thursday and Friday) at North Carolina State College in Raleigh, N. C. Registration for the conference will be from 9:30 a.m. to 1:30 p.m. on Thursday. The program for the conference follows:

Thursday, November 4

Morning Session

9:30 a.m. to 1:30 p.m. Registration.

10:00 a.m. Tour of School of Textiles

Afternoon Session

Presiding: *V. F. P. Sopwith*, Crompton & Knowles Loom Works

1:30 p.m.

Address of Welcome, *J. H. Lampe*, North Carolina State College

1:45 p.m.

Basic Industrial Electronics. *G. B. Hoadley*, North Carolina State College

2:30 p.m.

Electronic Control of Textile Machine Drives. *C. E. Robinson*, Reliance Electric and Engineering Company

3:15 p.m.

Electronic Controls for Temperature, Humidity, and Moisture Content. *L. F. Lawrence*, Minneapolis-Honeywell Regulator Company

4:00 p.m. Discussion Period

6:00 p.m. Social Hour, Tarheel Club

7:00 p.m. Barbecue Dinner, Tarheel Club

Friday, November 5

Morning Session

Presiding: *G. C. Caskie*, J. E. Sirrine & Company

9:30 a.m.

Report on the Application of Electric Heat to Textile Process of Drying. *Russell Ranson*, Ranson & Wallace Company

10:15 a.m.

Designing to Reduce Maintenance Costs. *A. W. Frankenfield*, E. I. du Pont de Nemours & Company

11:00 a.m.

Trouble Shooting on Motors and Control Equipment. *H. S. Colbath*, Bibb Manufacturing Company

11:45 a.m.

Report of the Conference Committee, *W. W. Hammond*. The Okonite Company

12:00 p.m.

Report on Textile Mill Enclosures. *Swafield Cowan*, Factory Insurance Association

12:30 p.m.

Lunch, Student Union Building, North Carolina State College

Afternoon Session.

Presiding: *J. D. McConnell*, Cone Mills Corporation

2:00 p.m. Maintenance of Electronic Control Equipment

In Knitting Mills. *C. R. Hyder*, Burlington Mills Corporation
In Weaving Mills. *H. A. Dameron, Jr.*, J. P. Stevens Company

2:45 p.m. Panel Discussion: Electrical Problems and Their Remedies

Moderator: J. D. McConnell

Discussion Leaders: *A. W. Frankenfield*, E. I. du Pont de Nemours & Company; *H. S. Colbath*, Bibb Manufacturing Company; *C. R. Hyder*, Burlington Mills Corporation; *H. A. Dameron, Jr.*, J. P. Stevens Company, Inc.; *J. R. Terrone*, Dan River Mills, Inc.; *F. D. Snyder*, Westinghouse Electric Corporation; *J. H. Homer*, Allis-Chalmers Manufacturing Company; *J. R. Adamson*, Charlotte Service Shop.

5:00 p.m. Tour of the Atomic Reactor Building, North Carolina State College

EJC Broadens Participation in Engineering Policy and Activity

To increase the engineering profession's unity, Engineers Joint Council has adopted two constitutional amendments which permit, under prescribed conditions, admission of national and local organizations not now meeting all qualifications for constituent membership. A special committee is drafting conditions for admission.

The Council at present is constituted of eight major engineering organizations with a total individual membership of 170,000. These are the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Water Works Association, American Institute of Electrical Engineers, Society of Naval Architects and Marine Engineers, American Society for Engineering Education and American Institute of Chemical Engineers.

The amendments were made effective by the Executive Committee on July 8, following affirmative action by each of the constituent societies. Total membership of at least 5,000 is required of a national organization to qualify as a constituent society. The first amendment permits admission as Associates of national organizations with less than 5,000 members.

The second amendment permits admission as Affiliates of societies "which are regional rather than national in geographical scope." This also allows entrance as Affiliates of federations of engineering societies (or of sections of such societies) broadly representative of the engineering profession when the majority of the societies that are federation members have qualifications for voting members equivalent to those required of Council's constituent societies.

In both instances, Associates and Affiliates, the one relating to national organizations and the other to local or regional organizations, admission would be without official vote. However, provision is made for representatives to participate in Council meetings.

These new amendments open the way for extending the scope of the Council to organizations which have important roles in the engineering profession, but which could not presently qualify under all conditions for constituent membership.

Steps taken to adopt the amendments were a consequence of suggestions made in 1951 by the Exploratory Group. This Group had been named to consider increased unity of the engineering profession and came forward with a number of proposals. One result of the early action of the Exploratory Group was the admission of the American Water Works Association, the Society of Naval Architects and Marine Engineers, and the American Society for Engineering Education as constituent societies of the Council.

Purposes of prospective Associates or Affiliates, under the new amendments, are within the scope of the objectives of the Council. These include: advancement of the general welfare of mankind through the available resources and creative ability of the engineering profession; co-operation of the branches of the profession; advancement of the science and profession of engineering; development of sound public policies in national and international affairs wherein the profession can be helpful through the services of members of the profession.

To achieve these objectives, Council acts as an advisory and co-ordinating agency to seek and study matters of mutual interest to the constituent societies, and to recommend parallel action by them; represents the constituent societies in instances in which these societies desire joint representation; administers, on behalf of the engineering profession, activities authorized by a majority of the constituent societies.

AIEE Officers to Be Nominated for 1955 Election

For the nomination of officers to be voted upon in the spring of 1955, the AIEE Nominating Committee will meet in New York, N. Y., in January 1955. The officers to be elected are: a president, a treasurer, three directors, and five vice-presidents, one from each of the even-numbered geographical Districts. Fellows only are eligible for the office of president; Members and Fellows for the offices of Vice-president, Directors, and Treasurer.

To guide this committee in performing its constituted task, suggestions from the membership are, of course, highly desirable. To be available for consideration of the committee, all suggestions must be received by the Secretary of the committee at Institute headquarters not later than December 15, 1954.

In accordance with the provisions in the constitution and bylaws, quoted in the follow-

ing paragraphs, actions relating to the organization of the Nominating Committee are now under way:

Constitution

29. There shall be constituted each year a Nominating Committee consisting of one representative of each geographical District, elected by its executive committee, one representative of each technical division elected by the division committee, and other members chosen by and from the Board of Directors not exceeding in number the number of technical divisions; all to be selected when and as provided in the Bylaws. The Secretary of the Institute shall be the secretary of the Nominating Committee, without voting power.

30. The executive committee of each geographical District shall act as a nominating committee of the candidate for election as vice-president of that District, or for filling a vacancy in such office for an unexpired term, whenever a vacancy occurs.

31. The Nominating Committee shall receive such suggestions and proposals as any member or group of members may desire to offer, such suggestions being sent to the secretary of the committee.

The Nominating Committee shall name, on or before January 31 of each year, one or more candidates for president, treasurer, and the proper number of directors, and shall include in its ticket such candidates for vice-presidents as have been named by the nominating committees of the respective geographical Districts, if received by the Nominating Committee when and as provided in the Bylaws; otherwise the Nominating Committee shall nominate one or more candidates for vice-president(s) from the District(s) concerned.

Bylaws

Sec. 23. During September of each year, the secretary of the Nominating Committee shall notify the chairman and secretary of the executive committee of each geographical District, and the chairman and secretary of each technical division committee, that, by December 15 of that year, each District and each technical division should select a representative to serve as a member of the AIEE Nominating Committee and an alternate to serve if the representative is unable to attend the meeting of the Nominating Committee. The names of representatives and alternates, so selected, should be transmitted by the above designated officers to the secretary of the Nominating Committee by December 15.

During September of each year, the secretary of the Nominating Committee shall notify the chairman and secretary of the executive committee of each geographical District in which there is, or will be during the year, a vacancy in the office of vice-president that by December 15 of that year, a nomination for a vice-president in that District made by the District executive committee should be in the hands of the secretary of the Nominating Committee.

Between October first and December fifteenth of each year, the Board of Directors shall choose a number of its members, not exceeding the number of technical divisions, to serve on the Nominating Committee, and notify the secretary of the Nominating Committee of the names of the members so chosen.

The secretary of the Nominating Committee shall give the members so selected not less than ten days' notice of the first meeting of the committee, which shall be held not later than January thirty-first. At this meeting, the committee shall elect a chairman and shall proceed to make up a ticket of nominees for the offices to be filled at the next election. To insure that full consideration be given to all suggestions from the general membership, they must be in the hands of the secretary of the committee by December fifteenth. The nominations as made by the Nominating Committee shall be published in the March issue of *Electrical Engineering*, or otherwise mailed to the Institute membership not later than the first week in March.

Independent nominations may be made in accordance with provisions in article VI, section 32, of the constitution and section 24 of the Bylaws, which are quoted in the following:

Constitution

32. Independent nominations may be made by a petition of twenty-five (25) or more corporate members sent to the secretary when and as provided in the Bylaws; such petitions for the nomination of vice-presidents shall be signed only by members within the District concerned.

Bylaws

Sec. 24. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with article VI, section 32 (Constitution), must be received by the secretary of the Nominating Committee not later than March 25 of each year, to be placed before that committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the Nominating Committee in accordance with article VI of the Constitution and sent by the secretary to all qualified voters on or before April 15 of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

(*Signed*) N. S. Hibshman
Secretary

Lamme Medal Nominations to Be Submitted by December 1

Members of the Institute again are reminded that they have an opportunity to submit nominations for the 1954 Lamme Medal. All nominations must be received not later than December 1, 1954.

Details regarding qualifications for the award were published in the June 1954 issue of *Electrical Engineering*, page 566.

Eta Kappa Nu to Hold 50th Anniversary Convention

The Eta Kappa Nu Association's "50th Anniversary Meeting" will be held Friday and Saturday, October 15 and 16, at the University of Illinois, Urbana, Ill. The electrical engineering honor society was founded at the University of Illinois on October 28, 1904.

During the first day of the meeting, an assembled convention of one official delegate from each college and alumni chapter and all members of the National Executive Council will take place. It is expected that the convention will vote to give members of the National Advisory Board and undergraduate and alumni members advisory and discussionary powers from the floor. Each delegate will be asked to propose and discuss new legislation which his chapter wishes to introduce and to report any problems his chapter has. These will be referred to committees to be appointed by the presiding officer.

On Saturday morning there will be a general session of the assembled convention. Each convention committee will report and the convention will take action on each report. At noon presentations will be made to past national presidents in attendance, and at 1:30 p.m. the 50th Anniversary Boulder-Plaque Dedication Ceremony will take place. There will also be other ceremonies.

GUIDED TOURS

Guided tours of the campus will be to the following places: electrical engineering buildings, digital computer, and betatron laboratories, other university projects, and inspection of exhibits of projects or activities of undergraduate chapters. Each registrant should designate his choices so as to help the committee in providing guides and transportation.

LADIES ENTERTAINMENT

The local committees will arrange for the wives of some faculty members to be present to entertain the ladies during the convention sessions and committee meetings. This is an open meeting and all friends of the association are invited.

RESERVATIONS

Requests for room reservations should be sent to Professor D. F. Hang, Department of Electrical Engineering, University of Illinois, Urbana, Ill.

Friday, October 15

9:00 a.m. Registration. Electrical Engineering Building

10:00 a.m. Informal Gathering in Electrical Engineering Lounge

12:00 p.m. Luncheon

Welcome address: D. J. Heid, president of Alpha Chapter

Remarks: J. E. Hobson, national president

2:00 p.m. General Afternoon Session

Presiding: J. E. Hobson

6:30 p.m. Dinner and Entertainment

8:00 p.m. Committee Meetings

Saturday, October 16

9:00 a.m. General Morning Session

11:45 a.m. Group Photograph of All Attending

12:00 p.m. Luncheon and Presentations to Past Presidents in Attendance

1:30 p.m. Fiftieth Anniversary Boulder-Plaque Dedication Ceremony

2:00 p.m. Guided Tours of Campus

4:30 p.m. Induction of Eminent Members

6:00 p.m. Banquet

Toastmaster: W. L. Everitt, University of Illinois, Presentation of College Chapter Award and Honorable Mentions
Announcement of Chapter Certificates
Introduction of newly inducted eminent members
Address by guest speaker

9:00 p.m. to 12:00 a.m. Golden Anniversary Dance (Informal)

Transformer Subcommittee Working Groups Correction

In the preliminary listing of the Institute's committee listings in the September issue of *Electrical Engineering*, the two working groups at the top of the middle column of page 850: Working Group on Revision of Guide for Loading Oil-Immersed Distribution and Power Transformers and the Working Group on Insulation Requirements for Specialty Transformers, should be under the heading of the Subcommittee on Insulation Life, instead of under the Subcommittee on Dielectric Tests. In this second working group, Mr. Fockler's initials should be W. G. instead of A. G.

Mr. J. L. Cantwell should also be listed as the Chairman of the Working Group on Life of Materials as well as Chairman of the Subcommittee on Insulation Life.

"Automation" the Subject at Philadelphia Sessions

Nine lecturers from a diversity of industry will bring facts and philosophy on the crusade for complete manufacturing mechanization at the joint AIEE–IRE Symposium on Automation.

There will be six Thursday evening sessions beginning on October 14, and ending on November 18. All the lectures, sponsored by the Philadelphia Sections of both societies, will take place at the Philadelphia Electric Company Auditorium, Edison Building, 9th & Sansom Streets.

Presentations will not only cover recent progress in mechanization, but plans for future endeavor. Application data will often be illustrated with new movies, and lectures will be designed to afford practical benefit to all engineers engaged in design, development, or production.

REGISTRATION

For professional society members who want to attend the complete series, the charge will be $3.00, for nonmembers $4.00. Single lectures will cost $1.00, payable at the door. Checks should be paid to the order of AIEE's Philadelphia Section.

Thursday, October 14

7:30 p.m. Session 1. Automation in the Automotive Industry

Recent Developments at the Ford Engine Block and Foundry Plant. *J. E. Cunningham*, Wilson Automation Company

Thursday, October 21

(Tentative)

7:30 p.m. Session 2. Electronic Auto-Assembly I

Automatic Fabrication in the Electronics Industry. *Clede Brunetti*, Mechanical Division, General Mills, Inc.

Thursday, October 28

7:30 p.m. Session 3. Electronic Auto-Assembly II

Automatic Wiring. *S. J. Begun*, Clevite-Brush Development Company

Thursday, November 4

7:30 p.m. Session 4. Electronic Auto-Assembly III

Flexible Control of Electronic Assembly Automation. *G. W. Gamble*, General Electric Company

Thursday, November 11

7:30 p.m. Session 5. Process Control

Instrumentation and the Analogue Computer in Process Control. *Professor D. P. Eckman*, Case Institute of Technology

Thursday, November 18

7:30 p.m. Session 6. Economic and Management Aspects of Automation

Symposium Chairman: I. L. Auerbach, Burroughs Adding Machine Company

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Power Division

Committee on Rotating Machinery (*E. I. Pollard, Chairman; M. L. Schmidt, Vice-Chairman; R. F. Edwards, Secretary*). Substantially all of the work of this committee is carried on through its subcommittees. The Insulation Subcommittee has recently published a proposed test code for the evaluation of insulation for random-wound rotating machines. Work is also well along on a similar test code for form-wound coils. This will accelerate the application of new insulating materials and may result in a new method of classifying insulation systems which will supplement or replace the traditional Classes A, B, C, and H.

Four subcommittees are revising test codes for machines. The code for polyphase induction machines has been submitted to American Standards Association (ASA) as a section of ASA-*C50*. The Fractional HP Subcommittee expects to approve a revision of the code for single-phase machines this month. Revisions of the direct-current and synchronous-machine codes are now in the preliminary draft stage.

Other major projects are: a proposed guide for operation and maintenance of turbine generators in the Synchronous Machine Subcommittee; a technical conference on motors for air-conditioning equipment, sponsored by the Fractional HP Subcommittee; preparation of definitions for the many varieties of magnetic clutches in the Clutch Subcommittee; and a series of technical sessions on basic theory and design methods for induction motors, sponsored by the Induction Machinery Subcommittee.

Committee on Transmission and Distribution (*F. V. Smith, Chairman; T. J. Brosnan, Vice-Chairman; J. T. Lunignan, Jr., Secretary*). Among the more important projects being carried on by the Subcommittees are: impulse characteristics of insulators (wood and air in series), fundamental basis for the insulation of transmission lines, and strength of wood poles.

Though much work has been done on impulse characteristics of insulators, there seems to be need of assembly and correlation. The matter is of major importance in the design of the higher-voltage wood-pole transmission lines.

The selection of the number of insulator units to give required lightning protection to transmission lines has been rather well established, but there are significant differences in methods of taking account of switching surges, atmospheric conditions, and hot line maintenance, among other factors. The subject is being studied in the expectation of presenting a comprehensive report.

As for the strength of wood poles, the American Society for Testing Materials (ASTM) is doing extensive research and reviewing present standards as to fibre stress, etc., since the subject is important to both transmission and distribution engineers. The committee is keeping in close touch with the program and welcomes suggestions as to aspects of the subject that should be explored.

AIEE FELLOWS ELECTED..

Board of Directors Meeting, June 24, 1954

William D. Cannon (AM '21, M '34), assistant to transmission research engineer, Western Union Telegraph Company, New York, N. Y., has been transferred to the grade of Fellow in the AIEE "for developments in instrumentation in the communications field." Mr. Cannon was born in Seaford, Del., February 21, 1895, and was graduated from the University of Delaware in 1918 with a bachelor of science degree. From 1918 to 1919 he was an engineer with Western Union Telegraph Company, New York, N. Y., doing mathematical work on the theory of ocean cable transmission and experimental work on the development of d-c earth potential correcting devices. The next 2 years were spent on a research fellowship at the University of Illinois, from which institution he received his master's degree in 1921. Since that time he has been associated with the Western Union Telegraph Company. From 1921 to 1925 he was an engineer engaged in continuation of his earlier mathematical work on ocean cable theory and developed a widely used neutralizing generator system for the mitigation of a-c induction from power systems into telegraph circuits. From 1925 to 1943 he was in charge of a group of engineers responsible for research and development on telegraph transmission and disturbance mitigation. He was responsible for a development which culminated in a transAtlantic photo service by ocean cable. From 1944 to 1945 he did government research work at Western Union's Water Mill Laboratory. Among the results of this work which can be disclosed was the development of a light source which can be efficiently modulated at audio and radio frequencies in the visible and infrared regions of the spectrum. Since 1945 he has been assistant to transmission research engineer, directing theoretical and mathematical work on projects such as submarine telegraph repeaters, high-speed time-division multiplexing, telegraph distortion measuring devices, and a simplified telegraph repeating relay. Recently the telegraph transmission work of Mr. Cannon has resulted in a great advance in the distortion measurement field. A small light-weight portable instrument affords instrument indication of both bias and fortuitous distortion. A method devised by Mr. Cannon for the measurement of envelope delay reduces this sort of instrumentation to a simple form which does not

William D. Cannon

Howard A. Enos

Carl R. Freehafer

Arthur R. Gatewood

require the employment of paralleling or return-timing circuits.

Howard A. Enos (AM '21, M '27), distribution engineer, American Gas and Electric Service Corporation, New York, N. Y., has been transferred to the grade of Fellow in the AIEE "for developments in power distribution systems, particularly low-cost rural electrification." Mr. Enos was born in Allegan County, Mich., April 4, 1891, and was graduated from the University of Michigan in 1917 with a bachelor of science degree in electrical engineering. After service with the Detroit (Mich.) Edison Company, and Consumers Power Company, Jackson, Mich., he became distribution engineer, Indiana Service Corporation, Fort Wayne, in charge of distribution engineering department. Since 1924 he has been distribution engineer for American Gas and Electric Service Corporation, New York, N. Y. He is in charge of the distribution engineering section, which includes planning and supervision of operation of distribution systems in the American Gas and Electric systems. Mr. Enos has promoted higher voltage rural lines in early stages of rural electrification, together with the use of steel-reinforced aluminum-cable conductors and long span construction, as well as the design of an early type of single-bushing rural transformer for direct pole mounting. He promoted the use of aluminum conductors for urban use and designed the first satisfactory and economical weatherproof braided covering for aluminum conductors. Mr. Enos suggested and promoted the manufacture and use of the first economical bare neutral supported service drop cable using aluminum conductors. He helped in the design of the first step voltage regulator and promoted the use and subsequent development of step voltage regulators. Mr. Enos has been responsible for many major improvements in materials and equipment for distribution systems. He took an important part in developing the Fifth Edition of the National Electrical Safety Code.

Carl Randolph Freehafer (M '40), vice-president, director and general manager of: Brazilian Telephone Company, Canadian corporation with headquarters in Toronto, Ont., Canada; vice-president and director of: Companhia Brasileira Administradora de Servicos Tecnicos, Brazilian corporation with headquarters in Rio de Janeiro, Brazil; Companhia Telefonica de Minas Gerais, Brazilian corporation with headquarters in Belo Horizonte, State of Minas Gerais, Brazil; Companhia Telefonica do Espirito Santo, Brazilian corporation with headquarters in Vitoria, State of Espirito Santo, Brazil; has been transferred to the grade of Fellow in the AIEE. He has been cited for "inspiring leadership contributing to effective solution of difficult problems in communication engineering." Mr. Freehafer was born in Reading Pa., December 30, 1891. He began his association with The Bell Telephone Company of Pennsylvania, Philadelphia, in 1910, as a service inspector. He became assistant traffic superintendent for Bell 1913–1914; clerk, traffic inspector, and engineer, 1914–1916. During World War I (1916–1917) he served with the U. S. Army, Troop A, 1st Pennsylvania Cavalry on duty at the Mexican border. From 1917 to 1919 he was with the 112th Infantry, 28th Division, serving in France. He was honorably discharged with the rank of Captain. Mr. Freehafer returned in 1919 to Bell as engineer and division force engineer, traffic department, Philadelphia and Pittsburgh; became district superintendent of traffic, Pittsburgh, in 1920; division superintendent of traffic and division traffic manager, 1923 to 1926; general traffic manager, 1926. As general commercial manager, 1928–36, he supervised commercial engineering work and made forecasts of telephone growth in detail in the western half of Pennsylvania. He determined also the proper rates for special and unusual types of customer service. In addition, he was responsible for customer and other public contacts, business office operation, training, personnel practices, business office methods, determination of rates charged for special services, collection of all moneys, and for coordination of activities with those of other operating departments in the same territory. From 1936 to 1937, he was Philadelphia general traffic manager. He became vice-president and general manager of the company's Eastern Area in 1937. This comprised the counties of Philadelphia, Delaware, Chester, Montgomery, and Bucks in Pennsylvania, and the state of Delaware. He had charge of all operations: engineering, commercial, plant, and traffic. Included was supervision of about 325 engineers, who planned, designed, specified, estimated, and supervised the construction of telephone plants. The entire organization covered by this engagement comprised about 11,900 people, rendering service to about 1,200,000 telephones. Mr. Freehafer became a staff vice-president in 1949. He was responsible for all operating activities dealing with engineering, commercial, plant, and traffic work in the states of Pennsylvania and Delaware. Important in this assignment was making engineering decisions concerning the construction program and technical phases of the operation, maintenance of telephone service, and rendering technical advice to the vice-president of operations and the president concerning such matters. In addition, he had responsibility for coordination of activities of the three operating areas of the company, and the integration of their work with that of the staff departments: personnel relations, public relations, legal, financial, and accounting. He has been a member of Franklin Institute; American Academy of Political and Social Science; The Newcomen Society; past president and former director, Engineers Club of Philadelphia. He has served on AIEE's Edison Medal Committee (1943–48) and Management Committee (1952–53).

Arthur R. Gatewood (M '41), chief engineer surveyor, American Bureau of Shipping, New York, N. Y., has been transferred to the grade of Fellow in the AIEE "for his contribution to the development and application of national and international standards relating to the installation of electrical equipment on shipboard." Mr. Gatewood was born in Philadelphia, Pa., November 6, 1899, and was graduated from Virginia Military Institute in 1918 with a degree in civil engineering and from Massachusetts Institute of Technology in 1921 with a degree in marine architecture and marine engineering. He has been associated with the American Bureau of Shipping since 1929. He was first employed as a surveyor on the technical staff analyzing plans covering the construction and installation of electric equipment and machinery for various ships, also supervising construction of new electric machinery for installation in ships and supervising repairs to electric equipment aboard ships. In 1937 be became principal engineer surveyor in charge of engine technical staff and formulation of the Bureau's rules for the construction, installation, and maintenance of ships including ship's service electric systems as well as electric propulsion. All of the merchant ships and all of the ships for the U. S. Army Transportation Corps built in the United States during World War II were constructed in accordance with these requirements. Since 1947 he has been chief engineer surveyor in responsible charge of all

Gordon W. Gerell

Hakon H. Haglund

Emerson E. Kimberly

George F. Lincks

the engineering work carried on throughout the world by the American Bureau of Shipping as a ship classification society. He is responsible for the formulation of the Bureau's rules for the construction, installation, and maintenance of electric propulsion machinery and ship's service electric equipment as well as all boilers, pressure vessels, steam reciprocating engines, turbines, internal combustion engines, gears, pumps, piping, shafting, propellers, steering gears, cargo refrigeration plants, engineering materials, and welding. Mr. Gatewood has served as American electrical engineering delegate to Safety of Life at Sea Conference, London, England, in 1948. He is a member of The American Society of Mechanical Engineers, Society of Naval Architects and Marine Engineers, American Welding Society, American Society of Refrigerating Engineers, and the British Institute of Marine Engineers and Institution of Mechanical Engineers. He is serving on the AIEE Committee on Marine Transportation (1941–54).

Gordon W. Gerell (AM '27, M '37), system superintendent of meters and relays, Union Electric Company of Missouri, St. Louis, has been transferred to the grade of Fellow in the AIEE "for his contributions to the improvement of electric service through advances in the application of protective relaying, and in preventive maintenances of oil-insulated apparatus." Mr. Gerell was born in Toronto, Ont., Canada, May 19, 1901, and was graduated from Washington University in 1924 with a bachelor of science degree in electrical engineering. Since his graduation he has been employed by the Union Electric Company of Missouri, St. Louis, in the substations department. Starting as a junior engineer, he was assigned work in connection with the installation and testing of automatic control equipment in the company's a-c and d-c substations. In responsible charge of the installation of control wiring for a d-c automatic substation consisting of two 1,800-kw motor-generator sets and a 2,220-kw rotary converter, he also was responsible for the calibration of all control relays and the testing of automatic control functions. In 1930 Mr. Gerell became interested in system relay protection and was given the responsibility for determination of protective relay settings for the system. He became system relay engineer in 1942. At the same time he assumed also the responsibility for the testing and maintenance of all system a-c and d-c substation automatic control testing. Considerable pioneer work was also done in the application of automatic oscillographs to the electric system, which were used for the analysis of relay operations and for the checking of system impedance constants and short-circuit values and fault locations. During this period he also was responsible for the insulation testing of major system equipment using the Doble techniques. In 1950 he became system superintendent of meters and relays. Beginning in 1943 Mr. Gerell instituted a program of original research upon the problem of determining the sludging characteristics of transformer insulating oil without taking the transformer containing the oil out of service. The direct result of this research was the development of the interfacial tension method of testing samples of insulating oil removed from transformers while in operation. Mr. Gerell is a member of the American Society for Testing Materials and has served on the AIEE Committees on Protective Devices (1936–40, 1947–49) and Relays (1953–54).

Hakon H. Haglund (M '28), assistant director of applied engineering, Western Union Telegraph Company, New York, N. Y., has been transferred to the grade of Fellow in the AIEE "for contributions to the mechanization of ocean telegraph cable operation." Mr. Haglund was born in Larvik, Norway, January 15, 1889, and was graduated from the University of Utah in 1921 with a bachelor of science degree in electrical engineering. All of his professional experience has been in the engineering department and the plant and engineering department of the Western Union Telegraph Company. From 1921 to 1924 he was engineering assistant working on transmission problems of the multiplex printing telegraph systems, including improvements in polar relays and development of an electrically controlled tuning fork having zero temperature coefficient. From 1925 to 1928 he was Western Union representative in development of multiplex equipment for the first trans-Atlantic permalloy loaded cable. From 1928 to 1943 he was ocean cable equipment engineer in responsible charge of group which designed and supervised manufacture and installation of multiplex equipment on all Western Union cables including the 1926 New York-London 8-channel simplex loaded cable and the 1928 Newfoundland-Azores duplex loaded cable. He was apparatus engineer in plant and engineering department in charge of applied engineering in connection with all Western Union telegraph equipment, both ocean cable and landline. This included equipment for the reperforator switching centers in the company's recent modernization and mechanization program and also involved initial testing of the field installations involved. Since 1951 he has been assistant director of applied engineering in the plant and engineering department. Mr. Haglund has served on the AIEE Committees on Communication (1933–37, 1947–49) and Telegraph Systems (1949–51).

Emerson E. Kimberly (AM '34, M '41), professor of electrical engineering, Ohio State University, Columbus, has been transferred to the grade of Fellow in the AIEE "for contributions in the field of electrical engineering education." Mr. Kimberly was born in Circleville, Ohio, October 17, 1895, and was graduated from Ohio State University in 1921 with a bachelor of electrical engineering degree. He received his master's degree from Ohio State in 1929. He has been a teacher of electrical engineering subjects since 1924, a professor since 1941. He has an active consulting engineering practice. Some of his more important jobs have included a survey of electric distribution system for Westerville, Ohio; economic study of plant of Toledo (Ohio) Auto Stamping Company and design of new electric system; electrolysis survey in Columbus; design and construction of automatic electric controller for first successful mechanical bowling pin setter and design of automatic bowling game scorer for Wolab Corporation, Springfield, Ohio; and design of new electric distribution system for pumping and filtration plants for Columbus. Professor Kimberly has done original work on analysis of shaded-pole induction motors and has contributed basic improvements in small single-phase motors. He is the author of "Electrical Engineering," a textbook used in a number of universities. He is also the author of several papers which have appeared in technical periodicals. He is a registered professional engineer in Ohio and is a member of the National Society of Professional Engineers, National Association of Power Engineers, the American Society for Engineering Education, and Sigma Xi.

George F. Lincks (AM '37, M '44), supervisor—lightning arrester and cutout systems engineering, General Electric Company, Pittsfield, Mass., has been transferred to the grade of Fellow in the AIEE "for contributions to co-ordinated fault protection of distribution systems." Mr. Lincks was born in Jersey City, N. J., January 10, 1901, and

after attending Pratt Institute, joined General Electric in 1920 as a test engineer, first at Schenectady, N. Y., and then at Pittsfield, Mass. From 1922 to 1930 he worked in design and development engineering of distribution cutouts. Mr. Lincks was largely responsible for the development of the oil-fuse distribution cutout. From 1930 to 1945 he was in charge of distribution cutout engineering section, being directly responsible for planning and execution of design, development, and application engineering work on distribution cutouts. He conceived and developed modern procedures for coordination of overcurrent protective devices on distribution systems. In 1945 he became section engineer, cutout engineering section, responsible for supervision, planning, and direction of design and development engineering and application of distribution cutouts. He conceived and developed the idea and application of the locked-closed distribution reclosed. Since 1953 he has been supervisor—lightning arrester and cutout systems engineering. He is responsible for supervising, planning, and directing the following engineering functions: application of lightning arresters and cutouts to electrical utility systems; preparation of bogey specifications for new or improved lightning arrester and cutout products; industry standards engineering in these fields.

Vernon M. Marquis (AM '23, M '31), vice-president and assistant to the president, American Gas and Electric Service Corporation, New York, N. Y., has been transferred to the grade of Fellow in the AIEE "for his contributions to the integration, interconnections, stable and economical operation of power systems." Mr. Marquis was born in Enid, Okla., March 30, 1898, and was graduated from Stanford University in 1921 with a bachelor's degree in mechanical engineering. He received the electrical engineering degree in 1922 from Stanford and the master of science degree in electrical engineering from Union College in 1923. From 1922 to 1928 he was associated with the General Electric Company, Schenectady, N. Y., first in the a-c design section and later in the central station engineering department handling the general application and power system design problems. From 1928 to 1942 he was on the engineering staff of American Gas and Electric Company. Some of his accomplishments include: directing studies and procedures for economical loading of generating plants on the basis of incremental fuel costs at major power stations; promoting full use of interconnections with other companies; developing and promoting automatic frequency and tie-line control; developing steam-turbine governor controls to provide better stability. During World War II, he served in the Power Branch of the Office of Production Management, Washington, D. C. He later became chief of the Power Division of the Office of War Utilities. From 1946 to 1949 he was system planning and operating engineer with the American Gas and Electric Service Corporation. He became vice-president in charge of system planning and operating in 1949, taking part in the negotiations leading to the formation of the Ohio Valley Electric Corporation and Indiana and Kentucky Electronic Corporation to supply 1,800,000 kw of firm power to Portsmouth, Ohio, diffusion plant of the Atomic Energy Commission. He has taken an active part in the technical design studies on the generation and transmission system on this project. He became vice-president and assistant to the president in 1954. He is a member of Sigma Xi and has served on the AIEE Committees on Power Generation (1940–45) and System Engineering (1947–49).

Herbert J. Reich (AM '32, M '43), professor of electrical engineering, Yale University, New Haven, Conn., has been transferred to the grade of Fellow in the AIEE "for his researches in electronics and his contributions to the technical literature." Dr. Reich was born on October 25, 1900, in Staten Island, N. Y., and was graduated from Cornell University in 1924. He received his master's degree in 1926 and his doctorate in 1928, also from Cornell. From 1924 to 1929 he was an instructor at Cornell University, Ithaca, N. Y., first in machine design, and later in physics. From 1929 to 1936 he was assistant professor of electrical engineering, University of Illinois, Urbana. He became associate professor in 1936 and professor in 1939. From 1944 to 1946 he was at the Radio Research Laboratory, Harvard University, Cambridge, Mass. He has been professor of electrical engineering at Yale University, New Haven, Conn., since 1946. Dr. Reich is the author of four textbooks and numerous technical articles. He is an editor of the D. Van Nostrand Company series in electronics and communications. Professor Reich has been a member of the Panel of Electron Tubes, Research and Development Board, New York, N. Y., since 1950. He is serving as a director of research projects for the U. S. Navy and the Central Intelligence Agency at Yale. He is a fellow of the Institute of Radio Engineers and the American Physical Society, and a member of the American Association for the Advancement of Science, and Sigma Xi.

Carl M. Skooglund (AM '22, M '32), chief electrical engineer, West Penn Power Company, Pittsburgh, has been transferred to the grade of Fellow in the AIEE "for contributions to electric system protection and electrical design of power plants." Mr. Skooglund was born in Kane, Pa., January 18, 1894, and was graduated from Pennsylvania State College in 1919 with a bachelor of science degree in electrical engineering. After a year as a signal apprentice, Pennsylvania Railroad Company, Pittsburgh, he returned to Pennsylvania State College, State College, Pa., as instructor in the electrical engineering department. He joined West Penn Power Company in 1921 as an assistant engineer, becoming power station design engineer in 1930, assistant electrical engineer in 1942, electrical engineer of power stations and substations in 1949, and chief electrical engineer in 1951. Mr. Skooglund's major responsibilities include review and approval of all station electrical expansion, research, design standardization, specification, and requisition of materials. He has done a great deal of work in connection with major power station additions, acting as liaison on electrical features between the company and the contractor. Mr. Skooglund also assists in the formulation of company policy regarding construction, maintenance, and operating suitability of electric equipment. Mr. Skooglund is a member of Eta Kappa Nu and Tau Beta Pi and is a registered professional engineer in Pennsylvania. He has served as chairman of the Pittsburgh Section of the AIEE.

Joseph Sticher (AM '30, M '39), division supervisor, electrical division of the engineering laboratory and research department, Detroit (Mich.) Edison Company, has been transferred to the grade of Fellow in the AIEE "for his contribution to the knowledge of the behavior of dielectrics in high-voltage cables." Mr. Sticher was born August 13, 1903, in Bochum-Linden, Germany, and received his technical education at the Academy for Technic of the State of Saxony, Germany, graduating as electrical engineer in 1925. After a brief period as an electrical engineer, Siemens and Halske Company, Berlin, Germany, he came to the United States in 1926 as a draftsman in the electrical department, Dodge Brothers Corporation, Detroit, Mich. In 1929 he joined the Detroit Edison Company as a research engineer engaged in studies of insulation under high electric stress, in particular oil-impregnated paper cable insulation under corona discharge. He had an important part in the 120-kv pipe-type cable installations. He investigated experimentally the ability of 24 kv to withstand emergency overloads and had a part in developing a method for determining emergency current ratings of cables by means of reduced scale models. He became senior research engineer in 1947 in charge of electrical research and test programs for electric cables. Very thorough studies have been made of the thermal and ionization characteristics of the 120-kv pipe cable of the high-pressure gas-filled type.

Photo by Bachrach

Vernon M. Marquis

Yale University News Bureau

Herbert J. Reich

Carl M. Skooglund

Joseph Sticher

Gregory S. Timoshenko

Harold R. Vaughan

George S. Whitlow

Other work has included studies of the ability of 24-kv cable to work at 41 kv and studies of induction heating problems. He became assistant head of electrical division of the engineering laboratory and research department in 1952 and division supervisor in 1954. At present, there are several research programs under his direction, such as determination of the effect of severe load cycles on compound drainage and ionization-starting potentials of various types of high-pressure gas-filled pipe-type 138-kv cable; and studies relating to the use of aluminum conductors for pipe-type cable. Mr. Sticher became an American citizen in 1932. He is a member of the National Research Council and the Engineering Society of Detroit. Mr. Sticher is serving on the AIEE Committee on Insulated Conductors (1953–54).

Gregory S. Timoshenko (AM '33, M '39), professor and head of the electrical engineering department, University of Connecticut, Storrs, has been transferred to the grade of Fellow in the AIEE "for his contribution to the advancement of engineering education." Dr. Timoshenko was born in St. Petersburg, Russia, November 1, 1904. In 1929 he received the degree of "diplom-ingenieur" in applied physics from Technische Hochschule, Berlin - Charlottenberg, Germany. He earned his doctor of philosophy degree in electrical engineering from the University of Michigan in 1932. From 1932 to 1934 he was a teaching assistant in electrical engineering and part-time research associate at the University of Michigan, Ann Arbor. From 1934 to 1939 he was instructor in electrical engineering at Massachusetts Institute of Technology, Cambridge, teaching undergraduate and graduate courses and doing research in gaseous electrical conduction and photometry. He became associated with the University of Connecticut in 1939 as assistant professor of electrical engineering, becoming associate professor in 1942 and professor and head of the electrical engineering department in 1946. During the summer of 1941 he was at the Nela Park Engineering Laboratories of the General Electric Company, Cleveland, Ohio, as research engineer for the U. S. Army on camouflage problems. He has been a consulting engineer on ignition problems and electrical measurement problems on superchargers for the Pratt and Whitney Aircraft Corporation, East Hartford, Conn., and research engineer on instruments and measurements for the Templetone Radio Corporation, New London, Conn., in 1944–45. He also has done consulting work for the Safety Car Lighting and Heating Company, Hamden, Conn., and the Connecticut Light and Power Company, Berlin. Dr. Timoshenko became an American citizen in 1936. He is a fellow of the American Physical Society, and a member of the American Society for Engineering Education, the Illuminating Engineering Society, and the Institute of Radio Engineers. He has served on AIEE Committee on Basic Sciences (1943–53).

Harold R. Vaughan (AM '31, M '41), district manager, engineering and service, Westinghouse Electric Corporation, Kansas City, Mo., has been transferred to the grade of Fellow in the AIEE "for his contributions in the field of turbine generator design and in the development of transmission systems." Mr. Vaughan was born in Independence, Kans., August 25, 1903, and was graduated from the University of Colorado in 1928 with a bachelor of science degree in electrical engineering. After graduation he joined the Westinghouse Electric Corporation, East Pittsburgh, Pa., and spent a year on the graduate student training course. Following that he spent 2 years as a design engineer on large rotating machines where he assisted in the development of a hydrogen-cooled turbine generator and a new line of structural steel turbine generators. He developed a method of measuring stray load losses in turbine generators. He transferred to the central station engineering department in 1931 and spent 2 years on power system studies, application of equipment, and development of insulation co-ordination practices. He was transferred to the Southwestern District engineering department, St. Louis, Mo., in 1933, and from that time until 1941 served as field consultant on problems of design and operation of power systems and the application of electric equipment for utility systems and large industrial plants. He developed a scheme of out-of-step blocking and selective tripping with distance-type relays. In 1941 he was transferred to the industry engineering department, East Pittsburgh, and during World War II served as Westinghouse consultant in problems of application and operation for electrical utilities and large industries in the north central area. During that period he was responsible for co-ordinating the development of the first all-electronic exciter for large a-c generators, and applied the first large shunt capacitor for voltage above 13.8 kv. He was transferred to the Kansas City office in 1945 as supervisor of the engineering and service department in that office. He was made manager in 1951 and district manager in 1953. He is the author of a number of technical papers and is a member of Tau Beta Pi, Eta Kappa Nu, The American Society of Mechanical Engineers, National Society of Professional Engineers, and has served on the AIEE Committee on Relays (1953–54).

George S. Whitlow (AM '29, M '39), electrical engineer, Union Electric Company of Missouri, St. Louis, has been transferred to the grade of Fellow in the AIEE "for contributions in the development of efficient transmission systems and the application of the heat pump." Mr. Whitlow was born in Hamburg, Ark., August 8, 1902, and was graduated from the University of Arkansas in 1924 with a bachelor of electrical engineering degree. After graduation, Mr. Whitlow began his professional career as a testman with the General Electric Company. He was soon put in charge of automatic switchgear testing, Schenectady, N. Y., and later transferred to design engineer. In that position, he designed and supervised the installation of many automatic substations. From 1928 to 1941 he was field engineer for General Electric in St. Louis, Mo. This period covered planning, design, construction, and service work involving practically all types of electric equipment for central station, industrial, and railway applications throughout the midwest and south central regions. Since 1941 he has been electrical engineer at the Union Electric Company of Missouri, St. Louis. He is in responsible charge of planning and designing several major system projects. Since its inception in 1946 he also has been responsible for the design and engineering direction of the company's heat pump project. This has included original refrigeration system designs and pioneering research on ground coils and thermal properties of soils. The results of this work have been the basis of design for all heat pumps thus far installed in the St. Louis area. Mr. Whitlow contributed a major portion of the planning and development as well as making major contributions to the design of a 138-kv transmission system for the St. Louis metropolitan area which materially reduced the annual power losses inherent in a large power system and further made available for future expansion load centers capable of delivering large blocks of energy. This system has expanded to a present or immediate future capacity of over 600,000

kva. The system connects three large substations, three power plants, and provides interconnections with neighboring utilities. Mr. Whitlow has served on the following AIEE committees: Automatic Stations, Substations (1941–49, Chairman, 1946–48); Power Co-ordinating (1947–48); System Engineering (1948–54); and the Standards Committee (1946–48); and Technical Program (1946–48).

AIEE PERSONALITIES.....

E. C. Jordan (M'45), professor of electrical engineering, University of Illinois, Urbana, has been appointed head of the department of electrical engineering. Dr. Jordan, a naturalized citizen of the United States, was born in Edmonton, Alta., Canada, December 31, 1910. He holds bachelor's and master's degrees in electrical engineering from the University of Alberta and the doctor of philosophy degree (1940) from Ohio State University. Before joining the University of Illinois staff as associate professor in 1945, he had had industrial experience in Canada, had been a Battelle Memorial Fellow at Ohio State University, Columbus, and had taught there and at Worcester (Mass.) Polytechnic Institute. He has been a full professor at Illinois since 1947 and has also directed important research programs. He is a fellow of the Institute of Radio Engineers and a member of the American Society for Engineering Education, Tau Beta Phi, Sigma Xi, and Eta Kappa Nu. He has served on the Research and Development Board of the U. S. Department of Defense and the International Scientific Radio Union, and took part in a survey of European engineering education and electronic research. Dr. Jordan is co-author of the book, "Fundamentals of Radio," and author of "Electromagnetic Waves and Radiating Systems."

H. F. McPhail (AM'19, F'42), recently retired as director of the Power Utilization Branch, U. S. Bureau of Reclamation, Washington, D. C., has been appointed head of the Hydroelectric Division of the Kuljian Corporation, Philadelphia, Pa. He will supervise the engineering and construction of water-power projects both in this country and abroad. During his 35 years of service with the Bureau of Reclamation, Mr. McPhail supervised the design and construction of Grand Coulee, Hoover, and Shasta Dams, as well as other large projects. Last year he was awarded a Citation of Distinguished Service for his role in developing the power program of the U. S. Department of the Interior.

A. W. Howard (AM'44), general manager, Calgary Power Company, Calgary, Alta., Canada, has been elected president of the Canadian Electrical Association for the 1954–55 term. **V. A. Ainsworth** (AM'35), Newfoundland Power and Light Company Ltd., St. Johns, was elected vice-president, Eastern Zone. **A. C. Abbott** (M'46) and **W. R. Way** (M'42, F'53), Shawinigan Water and Power Company, Montreal, Que., were elected to the Executive Committee representing the utilities. **K. V. Farmer** (M'21), Canadian Ohio Brass Ltd., Niagara Falls, Ont.; **I. M. MacLean** (AM '21), Canadian General Electric Company Ltd., Toronto, Ont.; and **J. M. Thomson** (AM'26, F'47), Ferranti Electric Ltd., Toronto, have been elected to the Executive Committee representing the manufacturers. A graduate of the University of Toronto in 1935, Mr. Howard has been general manager of Calgary Power since 1952. He is a member of the Engineering Institute of Canada, Corporation of Professional Engineers of Quebec, and the Association of Professional Engineers of Alberta. Mr. Way has served the AIEE as vice-president, District 10 (1951–53) and on the Committees on Power Generation (1945–46), Membership (1947–49), and System Engineering (1951–53). Mr. Thomson has served the Institute as vice-president, District 10 (1939–41) and as a member of the following committees: Edison Medal (1940–45); Sections (1939–44); and Electrical Machinery (1939–41).

R. A. Schatzel (AM '28), vice-president and director of engineering, Rome (N. Y.) Cable Corporation, has been elected vice-president of the American Society for Testing Materials for a 2-year term. Born in Kingston, N. Y., Mr. Schatzel received his bachelor of science degree in chemistry from Union College in 1921 and his master's degree in 1923. He was research chemist, General Electric Company Research Laboratory, and later took graduate work and instructed at Massachusetts Institute of Technology, Cambridge. In 1924 he was assistant research director, Rome Wire Company, and from 1927 to 1935 was technical director of General Cable Corporation; then for 10 years was director of research in Rome and Bayonne, N. J. Since 1945 he has been vice-president and director of engineering, Rome Cable Corporation. During World War II he was active on the War Production Board. He is a fellow of the American Institute of Chemists, and a member of the American Chemical Society, American Society for Metals, American Association for the Advancement of Science, American Institute of Mining and Metallurgical Engineers, American Society of Naval Engineers, British Institute of Metals, British Institute of Rubber Industry, Insulated Power Cable Engineers Association, and a member of the editorial advisory board of *India Rubber World*. He is serving on the AIEE Committee on Insulated Conductors (1947–54).

W. W. McDowell (AM'52), director of engineering, International Business Machines Corporation, New York, N. Y., has been elected vice-president. Mr. McDowell is in charge of the company's research and engineering development work.

W. H. T. Holden (M'33), consulting engineer, Pasadena, Calif., has been elected president of the California Society of Professional Engineers. Mr. Holden was employed by the Westinghouse Lamp Company, 1920–21; American Telephone and Telegraph Company, New York, N. Y., 1921–34; Bell Telephone Laboratories, New York, 1934–50; and was an evening instructor at Pratt Institute, Brooklyn, N. Y., during 1930–50. He entered consulting practice in California in 1950. Mr. Holden is a member of Phi Beta Kappa and Sigma Xi.

C. H. Black (AM'41, M'45), general manager, meter and instrument department, General Electric Company, Lynn, Mass., has been named general manager of the new instrument department of the company at Lynn; and **D. E. Craig** (AM'45, M'49), manager, Somersworth (N. H.) plant, has been named general manager of the new meter department of General Electric with headquarters at Somersworth. Staff of the new instrument department will include **J. C. Garrett** (AM'42, M'53), as manager-marketing, and **I. F. Kinnard** (AM'21, F'43), as manager-engineering. New managers in the meter department include **B. B. Gravitt** (AM'36, M'48), as manager-marketing, and **G. R. Sturtevant** (AM'30, M'39), as manager-engineering. A native of Baltimore, Md., Mr. Black was graduated from Johns Hopkins University with a bachelor's degree in electrical engineering. He joined General Electric at Schenectady, N. Y., as a student engineer in 1924. Following various assignments in the switchboard department, he was transferred to Philadelphia where he served as an application engineer. In 1929 he was named supervisor of the switchgear model room and secretary of the switchgear development committee. In 1930 he was placed in charge of engineering for metalclad switchgear equipment and the following year was appointed engineer for the air circuit breaker division. In 1942 Mr. Black was transferred to the company's Trenton, N. J., switchgear plant where he was in charge of engineering and manufacturing operations. Two years later he was named manager of engineering for the switchgear department, Philadelphia, Pa., and in 1948 was appointed manager of engineering for the Construction Materials Division. Mr. Black was made general manager of the former meter and instrument department in 1951. He has served on the AIEE Committee on Protective Devices (1944–45) and Switchgear (1947–48). Mr. Craig was born in Sioux Falls, S. Dak., and was graduated from South Dakota State College with a bachelor of science degree in electrical engineering in 1932. He joined General Electric in 1936, following service with the Northern States Power Company in South Dakota, Iowa, and Minnesota. In 1937 he was assigned to the distribution systems department where he held a number of supervisory posts, becoming manager of unit substation sales in 1945. Mr. Craig was appointed assistant manager of sales for the former meter and instrument department in 1949, and in 1951 was made manager of marketing. He was named manager of the Somersworth plant in 1952.

J. R. Bradburn (M'50), executive vice-president, ElectroData Corporation, Pasadena, Calif., has been elected president of the firm, which is the electronic computer affiliate of Consolidated Engineering Corporation. A graduate of the California Institute of Technology, Mr. Bradburn joined Consolidated Engineering in 1945 as treasurer and assistant to the president. In 1946, he became director of sales and vice-president in charge of commercial engineering, and subsequently served as vice-president and director of engineering. In 1953 he was named vice-president and director of Consolidated's computer division, becoming executive vice-president of ElectroData in 1954. Prior to World War II service as a major, he held posts with the General Electric Company and the Eastman Kodak Company. Mr. Bradburn is a member of Tau Beta Pi, the Instrument Society of America, and the Association for Computing Machinery. He is a registered engineer in California.

Leon Podolsky (M'45), technical assistant to the president, Sprague Electric Company, North Adams, Mass., has been appointed chairman of a new group to review all military electronic component part specifications with a view toward improving the performance of these components in the light of equipment requirements for new, very high reliability applications. Mr. Podolsky, who headed similar military task force engineering committees during World War II, was requested to undertake this chairmanship by the Office of the Assistant Secretary of Defense for Applications Engineering.

R. E. Tarpley (AM'29, M'47), supervisory research technologist, Leeds and Northrup Company, Philadelphia, Pa., recently observed the 25th anniversary of his employment with that company. Mr. Tarpley joined Leeds and Northrup in 1929, after receiving his master of science degree from the University of Illinois. He holds several patents and is joint author of a number of papers for scientific magazines. Mr. Tarpley is a member of the Institute of Radio Engineers and the Franklin Institute.

Henry Blackstone (AM '39), president, Servo Corporation of America, New Hyde Park, N. Y., has been appointed a member of the National Council of Consultants and vice-chairman of the Procurement and Production Committee of the Small Business Administration.

M. N. Waterman (AM '49), assistant manager, commercial engineering, Lamp Division, Westinghouse Electric Corporation, Bloomfield, N. J., has been elected vice-president of the Illuminating Engineering Society. **G. J. Taylor** (M '44), eastern sales manager, Day Brite Lighting, Inc., New York, N. Y., has been elected treasurer, and **D. M. Finch** (AM '48), associate professor of electrical engineering, University of California, Berkeley, has been elected a regional vice-president of the society. Mr. Waterman has served on the AIEE Committee on Production and Application of Light (1950–54).

V. B. Honsinger (AM '41), engineer-in-charge, research laboratory, Norwood (Ohio) Works, Allis-Chalmers Manufacturing Company, has been named assistant to the general manager in charge of the electrical product development laboratory. Mr. Honsinger, an alumnus of the University of Michigan, completed Allis-Chalmers' training course for graduate engineers in 1942 and then was assigned to Norwood Works. He had supervised the laboratory's activities from the time of its construction in 1947 and became engineer-in-charge of the research laboratory in 1949.

W. B. Wilson (M '53), application engineer, apparatus industrial power engineering section, General Electric Company, Schenectady, N. Y., has been appointed manager of the company's industrial power generation unit. A native of Sparta, Tenn., Mr. Wilson attended Maryville College and is a graduate of the University of Tennessee where he was awarded his bachelor of science degree in mechanical engineering. He did postgraduate work at Massachusetts Institute of Technology and Cornell University. Mr. Wilson started with General Electric on the test course, transferring to the turbine engineering department at Lynn, Mass. Mr. Wilson is a member of The American Society of Mechanical Engineers, American Petroleum Institute, Technical Association of the Pulp and Paper Industry, Tau Beta Pi, and Phi Kappa Phi.

R. M. Darrin (AM '28, M '34), commercial vice-president in charge of customer relations, New York and New England areas, General Electric Company, New York, N. Y., retired July 1, 1954. Mr. Darrin was named a commerical vice-president of the New England district in 1949 with headquarters at Boston, Mass. In 1951 he was transferred to the New York office in charge of both New England and New York areas. A native of Corning, N. Y., Mr. Darrin attended Amherst College, served 2 years as a first lieutenant during World War I, and joined General Electric at Pittsfield, Mass., in 1919. Following executive assignments at General Electric district offices at Buffalo and Syracuse, N. Y., he was transferred to New York in 1945 as district manager of transportation for the Apparatus Division. In 1947 he was named manager of customer relations for the Central Stations Division, Schenectady, N. Y., remaining in that position until his Boston assignment in 1949. He is a member of The American Society of Mechanical Engineers.

M. E. Schlenker (AM'52), Reliance Electric and Engineering Company, Cleveland, Ohio, has been appointed to the Chicago, Ill., sales engineering staff of the company. Born in Frederick, S. Dak., Mr. Schlenker joined Reliance in November 1953, following 2½ years previous experience in the electrical industry. He is a graduate of South Dakota State College.

J. R. Werth (M'41), formerly with the South American subsidiaries of Electric Bond and Share Company in Brazil, has retired and is living in Richmond, Va.

Glenn Koger (M'47), Rome Cable Corporation, Rome, N. Y., has been appointed manager of the company's Torrance, Calif., plant. Mr. Koger is an electrical engineering graduate of Kansas State College in the class of 1929. He was with the General Electric Company for 19 years, 17 years of that time in the insulated wire department at Bridgeport, Conn. In 1949 he joined Walker Brothers, Conshohocken, Pa., as vice-president in charge of copper products and a director of the company. He joined Rome Cable Corporation in March 1954. Mr. Koger has served on the AIEE Committee on Insulated Conductors (1948–49).

G. M. Roy (AM'49), acting head, design staff, Nuclear Division, General Electric Company, Richland, Wash., has joined the staff of the atomic power study of the General Electric Company's Atomic Products Division, Schenectady, N. Y. Before joining General Electric at the Hanford plant, Mr. Roy taught electrical engineering for 2 years at the California State Polytechnic College, San Luis Obispo. During World War II, he served as an engineering officer in the Navy for 3 years, part of the time in the Naval Research Laboratory, Washington, D. C. He received a bachelor of science degree in electrical engineering from Tulane University in 1944, and a master's degree from Stanford University in 1947.

H. M. McNeil (AM '51), proposition engineer, wire and cable department, General Electric Company, Bridgeport, Conn., has been appointed wire and cable specialist of the Construction Materials Division. Mr. McNeil joined General Electric as a test engineer at Lockland, Ohio. He is a graduate of the University of Utah with a bachelor of science degree in electrical engineering. During World War II, he served in the U. S. Navy. Mr. McNeil has been assigned to the division's Denver, Colo., office.

A. F. Pelster (AM '42, M '48), section manager, application engineering department, Jack and Heintz, Inc., Cleveland, Ohio, has joined the Leland Electric Company, Dayton, Ohio, as manager—application engineering—air-borne equipment.

MEMBERSHIP • • •

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary, before October 25, 1954, or December 25, 1954, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Barr, S. M., Western Union Telegraph Co., New York, N. Y.

Todd, A. C., Fournier Institute of Technology, Lemont, Ill.

Williamson, W. A., Electric Panel Mfg. Ltd., Vancouver, B. C., Canada.

Wood, H. O., Philco Corp., Philadelphia, Pa.

4 to the grade of Member

OF CURRENT INTEREST

Materials Testing Reactor Tests Effects of Neutron Radiation on Materials

The Materials Testing Reactor (MTR), a recent development at the Atomic Energy Commission's National Reactor Testing Station in Idaho, has the highest neutron flux of any reactor now in existence. Thirty-thousand kw of heat are produced within a space about the size of 2 large suitcases. To provide a maximum density of both fast and thermal neutrons, the Uranium-235 in the MTR must fission at a high rate, with the release of high power per gram of fuel. A flow of over 300 gallons of water per second is needed to remove the heat.

Foremost purpose of the MTR is to test the effects of intense neutron radiation on materials and fuel elements to be used in future reactors which will operate at high fluxes and specific power, under simulated operating conditions of temperature, pressure, and particular coolant. Simultaneously the MTR is used in fundamental experiments in nuclear physics, for which its high flux makes it unique, the production of radioisotopes, and many other purposes. The high intensity of flux—10 to 100 times that available elsewhere—reduces the irradiation time and produces to a marked degree effects barely discernible in lesser neutron fields.

This high flux reactor is a joint enterprise of the Oak Ridge National Laboratory and the Argonne National Laboratory. Phillips Petroleum Company was appointed operating contractor under the jurisdiction of the Idaho Operations Office, Atomic Energy Commission. Cost of construction was approximately $18,000,000.

Construction was started in May 1950, and was ready for initial testing in February 1952. The reactor became critical, i.e., chain reacting, on March 31, 1952, at 11:19 p.m.; attained full design power on May 22, 1952; and has operated smoothly for nearly two years with almost no loss of time due to shutdowns except those constituting a regular part of the operating program.

The MTR is a thermal (slow) neutron reactor using uranium enriched in isotope U-235 as fuel, ordinary water as both moderator and coolant, and beryllium as the reflector. Because of its high specific power, average neutron fluxes of 2×10^{14} thermal neutrons per square centimeter per second (n/cm²/sec) and 1×10^{14} fast

South and west faces of the Materials Testing Reactor at the National Reactor Testing Station showing research equipment. The neutron tunnel of the neutron "chopper" extends from the southeast corner. The crystal neutron spectrometer with its shielding is in the foreground. The balcony, part way up the reactor face, holds recording panels for experimental apparatus

Future Meetings of Other Societies

Standards Engineers Society. Annual Meeting. October 1–2, 1954, Haddon Hall, Atlantic City, N. J.

National Federation of the Radioelectric and Electronic Industries of France. 17th French Radio and Television Exhibition. October 2–12, 1954, Musee des Travaux Publics, Paris, France

National Electronics Conference. 10th Annual Conference. October 4–6, 1954, Sherman Hotel, Chicago, Ill.

Society of Automotive Engineers. National Aeronautic Meeting. October 4–9, 1954, Hotel Statler, Los Angeles, Calif.

Institute of Radio Engineers—Professional Group on Nuclear Science. 1st National Annual Meeting. October 6–7, 1954, Sherman Hotel, Chicago, Ill.

American Chemical Society. 8th National Chemical Exposition. October 12–15, 1954, Chicago Coliseum, Chicago, Ill.

Audio Engineering Society. Annual Convention. October 13–17, 1954, Hotel New Yorker, New York, N. Y.

National Association of Corrosion Engineers. South Central Region Meeting. October 14–15, 1954, Dallas, Tex.

Radio-Electronics-Television Manufacturers Association. Radio Fall Meeting. October 18–20, 1954, Hotel Syracuse, Syracuse, N. Y.

Society of Automotive Engineers. National Transportation Meeting. October 18–20, 1954, Sheraton Plaza Hotel, Boston, Mass.

American Institute of Consulting Engineers. Annual Dinner Meeting. October 19, 1954, Waldorf Astoria Hotel, New York, N. Y.

American Society of Safety Engineers. Annual Meeting. October 19, 1954, Conrad Hilton Hotel, Chicago, Ill.

Engineers' Council for Professional Development. 22d Annual Meeting. October 28–29, 1954, Hotel Alms, Cincinnati, Ohio

Society for Advancement of Management. Annual Fall Meeting. October 28–29, 1954, Hotel Statler, New York, N. Y.

Aircraft Electrical Society. Annual Display Meeting. October 28–29, 1954, Pan-Pacific Auditorium, Los Angeles, Calif.

American Welding Society. National Fall Meeting. November 1–5, 1954, Sherman Hotel, Chicago, Ill.

Association for Applied Solar Energy. World Symposium. November 2–5, 1954, Phoenix, Calif.

Institute of Radio Engineers. East Coast Conference on Airborne and Navigational Electronics. November 4–5, 1954, Sheraton-Belvedere Hotel, Baltimore, Md.

Polytechnic Institute of Brooklyn. Symposium on Modern Advances in Microwave Techniques. November 8–10, 1954, Engineering Societies Building, New York, N. Y.

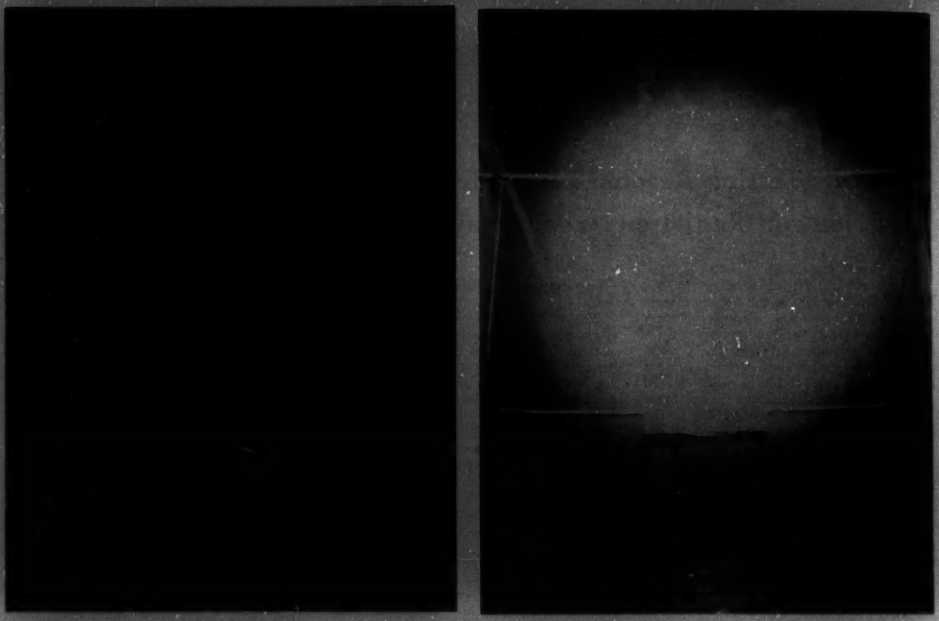
Industrial Management Society. Annual Time and Motion Study and Management Clinic, November 10–12, 1954, Sherman Hotel, Chicago, Ill.

American Society for Quality Control–Institute of Radio Engineers. National Symposium on Quality Control and Reliability in Electronics. November 12–13, 1954, Statler Hotel, New York, N. Y.

Operations Research Society of America. Fall Meeting. November 19–20, 1954, Sheraton-Park Hotel, Washington, D. C.

The American Society of Mechanical Engineers. Annual Meeting. November 28–December 3, 1954 Statler Hotel, New York, N. Y.

American Society of Refrigerating Engineers. 50th Annual Meeting. November 28–December 1, 1954, Ben Franklin Hotel, Philadelphia, Pa.



The blue glow (left), or Cerenkov radiation (right), emanating from irradiated fuel elements of the Materials Testing Reactor is visible light produced when charged particles transverse a transparent medium with a velocity exceeding the velocity of light in the medium. The uranium fuel elements are held in the reactor canal while awaiting chemical processing to remove fission products. While there, they form the most intense known source of 10^4 to 10^7 roentgens per hour available

n/cm²/sec are available. Peak thermal neutron fluxes of 5×10^{14} n/cm²/sec exist in certain positions in the reflector. Neutrons at the instant of release by fission, called "fast," travel with tremendous speed. They lose speed in collisions with the atoms of moderator until they settle down to what is called the "thermal" speed—about 5,000 miles per hour.

The enriched-uranium fuel is contained in an "active core" which is located inside a "lattice" region 16 × 28 inches in area and 24 inches high. It is surrounded by a 3-foot-high reflector made of beryllium. Both the lattice and the reflector are enclosed in a 55-inch-diameter aluminum tank which is extended by stainless steel sections above and below to form a 30-foot-deep "well", which is closed top and bottom with heavy lead-filled steel plugs. The top plug is removable when the reactor is not running so that the fuel in the lattice can be replenished and the beryllium in the reflector changed to accommodate experiments. The radioactive fuel elements and other pieces are lifted with grappling tools and lowered through a chute and valve mechanism in the bottom of the reactor tank into a canal holding 18 feet of water. The reactor tank is always kept filled with water for shielding as well as for cooling, and unloading operations are conducted by working through 20 feet of water.

Mounted on the top plug are the driving mechanisms for the rods controlling the reactor's rate of fission. The basic principle of control is to insert cadmium, a strong absorber of neutrons, close to fuel elements to stop the chain reaction, and to remove it just far enough to permit the chain reaction to proceed without multiplying out of control. As fuel is consumed, the cadmium is pulled farther out. There is a fuel section below the cadmium part of the control rods so that fuel is pulled into the active lattice as the cadmium is removed. This prolongs the time the reactor will function between shutdowns. In case of emergency all control rods drop by gravity to bring their cadmium sections into the active lattice. (This is called a "scram.")

In order to provide additional space having thermal neutron fluxes above 10^{13} n/cm²/sec, a secondary reflector of graphite divided into two zones is placed outside the reactor tank. The outer zone is a wall about 3 feet thick, built up of graphite blocks, enclosing the inner zone, a volume about 7 feet square and 9 feet high surrounding the aluminum tank. This inner zone is filled with some 700,000 graphite balls 1 inch in diameter. These can expand freely as they heat and can be replaced easily if damaged by the intense radiation close to the tank. Cooling air flows over the balls and through holes in the solid graphite.

Completely surrounding the graphite wall is a thermal shield, consisting of 4-inch-thick layers of steel, which absorbs most of the heat flowing from the graphite and in which most of the residual energy of the radiation from the reactor is given up. A 4-inch space between the plates provides a passage for cooling air.

Finally, a 3,000-ton concrete shield about 9 feet thick reduces the radiation escaping to such a small value that people may work safely around the reactor. The outer dimensions of the structure form roughly a 32-foot cube. Barytes (barium sulphate) aggregate is used instead of conventional gravel because its greater density permits a thinner shield to be used.

The reactor lattice and the beryllium reflector are cooled by water flowing at a rate of 20,000 gallons per minute. This water enters the well at 100 F and leaves at 111 F. It is fed by gravity from a 170-foot-high tank through the reactor tank to a vacuum spray evaporator system for cooling and degassing, and is then pumped back to the tank. The water for cooling is highly purified so that the minimum possible radioactivity is induced in it as it passes through the reactor. To further prevent the build-up of radioactivity in cooling water a small amount is continuously removed to a retention basin where it is held until its radioactivity has decayed to the point where it is no longer a health hazard.

The graphite reflector and thermal shield generate heat equivalent to about 500 kw by absorption of neutrons and gamma rays. They are cooled by air flowing at a rate of 25,000 cubic feet per minute. Large blowers in a fan house create a suction in the reactor structure so that the air is taken from the reactor building. It is discharged to the

atmosphere through a 250-foot-high stack. The air is filtered before passing through the reactor to remove particles which might become radioactive.

The experimental facilities of the MTR are as varied and flexible as possible. Provision is made for bringing a neutron beam outside the reactor for use in a crystal spectrometer and a time-of-flight spectrometer, or "neutron chopper." Most of the experimental work, however, consists in irradiating materials in various positions inside the reactor.

Several sections of the beryllium reflector inside the reactor tank are designed for easy replacement by special reflector pieces of beryllium or aluminum with the proper size holes to receive materials to be irradiated. The material under investigation is generally encased in aluminum cylinders. Irradiation continues during the complete operating cycle of 2 or 3 weeks. In many cases it is possible to bring instrument leads and other connections outside the reactor through gasketed access holes adjacent to the top plug.

The main "beam" holes are accessible at the outer face of the concrete shield and extend inward horizontally to the reactor lattice through "thimbles" projecting into the reactor tank. The inner ends of most of these holes are 6 inches in diameter. Since these holes penetrate to the highest flux in the reactor they are potentially hazardous from a radiation viewpoint and their use is correspondingly difficult and complicated. Each must be filled with a shielding plug during reactor operation.

The parts of plugs are made of beryllium where they reside in the beryllium reflector, or graphite in the graphite reactor, iron through the thermal shield, and concrete in the biological shield. For experimental work, a new plug with the experimental equipment attached to the front end or imbedded in the plug, and properly cooled, must be designed and built. Instrument leads, cooling connections, etc. can be brought outside. Since the portions of any plug inside the thermal shield become highly radioactive, heavy lead-shielded casks are required for handling them. A so-called "universal coffin" is provided to handle the beam hole plugs. The front end of the coffin has 10 inches of lead for shielding the beryllium parts of these plugs. The gross weight is 41,000 pounds.

In addition to these main experimental holes there are six more which run through the graphite wall. Four of these are for experimental work and two for reactor control instruments. They are either 4 or 8 inches in diameter.

Shuttle tubes are pipes about 1 inch in diameter penetrating the reactor structure close to the lattice. By means of either air or water pressure, shuttles containing the experimental material can be driven to the region of high flux and retrieved even during reactor operation. Thus short-time irradiations may be made.

Much irradiation space at reduced neutron fluxes is available in holes which penetrate into the graphite. The dimensions range generally from 2 to 4 inches in diameter. There is also space in four 6-inch thimbles which extend into the cooling water. A high-gamma neutron-free flux is also available for experimental purposes.

A "thermal column," 6 feet square and 8 feet long, built up of graphite blocks provides a very pure thermal neutron flux.

The fuel units on discharge from the reactor and before shipment for chemical processing have to be stored under water in the canal for several weeks because of the intense radioactivity and the thermal energy still remaining in them. By stacking these units in a rectangular array, an intense field of essentially pure gamma radiation has been made available.

Most materials placed in the reactor tank or graphite reflector are subject to considerable heating from the gamma rays which arise from fission, fission product decay, and neutron captures in structural material. The values go from 5 watt per gram to 0.10 watt per gram in the beryllium reflector.

Thermal fluxes ranging from 2×10^{8} to 5×10^{14} n/cm²/sec are highest in the beryllium and least in the thermal column. Fast flux is highest in the lattice.

The reactor building is approximately 130 feet square and 80 feet high. There is a wing 130 by 140 feet which provides laboratory space.

In a separate building is a large "hot cave" for examining materials in air. This is similar to the caves developed by Argonne National Laboratory. It will handle materials which have of the order of 10,000 curies of 1.5 to 3.0 mev gamma activity. A pair of Argonne Master-Slave Manipulators and one General Mills Manipulator are installed.

The MTR Policy Board of the Atomic Energy Commission establishes the priorities for irradiations in the reactor. The Phillips Petroleum Company assigns members of its technical and engineering staff to work with the experimenter on the design and construction of his apparatus. Some 30 Atomic Energy Commission laboratories or contractors are conducting work at the MTR, and about 100 irradiations are in progress.

Space in both high and low flux regions has now been made available, on a limited basis, for irradiations for the public.

Other installations at the National Reactor Testing Station include: Experimental Breeder Reactor, a generator of the first usable electricity from nuclear energy; Submarine Thermal Reactor, a land-based prototype of the nuclear engine for the first atomic-powered submarine, U.S.S. Nautilus; Chemical Processing Plant, built to recover nuclear fuel from used reactor fuel elements; and Aircraft Nuclear Propulsion Facilities, for ground testing in connection with the nuclear propulsion program.

New Tools Reveal Microscopic Secrets of Nature to Researchers

During the past fifteen years, with the help of the electron microscope and electron diffraction, researchers have uncovered many of nature's secrets concerning infinitesimal organisms and particles of matter which surround us and are vital to everyday life.

Today, the most modern electron microscopes employ accelerating voltages that are continuously variable from 40 to 100 kv to magnify tiny specimens 1,000 to 80,000 times actual size. Cameras are standard accessories with these instruments and film techniques readily permit magnifications up to 300,000. To understand such a magnification, a quarter dollar magnified by this amount would become $4^{1}/_{2}$ miles across.

The specimen must be very thin and because of this, must be adequately supported, as for instance by means of a grid. Aqueous dispersions of particles are applied to the grid or holders with a medicine dropper. Excess liquid is removed by touching the edge of the holder with a blotter. The thin film is allowed to dry and is checked under an optical microscope for breakage and particle density before examination in the electron instrument.

Oxide smoke particles from metals such as Mg, Cd, Zn, and Mo can be caught on a grid or holders without a supporting film. Specimens of this kind make good test objects for both electron microscopy and electron diffraction.

The technique of shadow casting is frequently employed in the preparation of specimens. When a metal is deposited obliquely on a specimen by vacuum evaporation, projections cast permanent shadows. This accentuates the third dimensional effect and usually enhances surface structure appearance. To shadow-cast a specimen, an electrically heated filament is located at a selected angle above the specimen. Choice of distance is such that metal atoms arrive at the specimen moving in almost parallel straight lines. The best angle to employ depends on the degree of surface roughness. There are many tricks to the trade in shadow casting. For example, too heavy a coating obscures fine structures; too small an angle results in loss of detail behind projections; sometimes it is advantageous to shadow-cast in two vertical directions; or heights and depressions may be more readily appreciated by the eye if micrographs are shown as negative prints.

Metals for shadow casting should not show a granularity comparable in magnitude with the structural surface details to be studied. Since it is desirable to secure adequate contrast with a minimum thickness of deposit, the density of the shadowing material is important. A number of metals have been found satisfactory for shadow casting such as Cr, Ni, Ge, Mn, Pd, Pt, and U. Cr is probably used more than any other.

When a specimen of bulk material is to be examined in the electron microscope, it must be very thin—about 0.1 micron. The problem of cutting such a specimen from a piece of cancerous tissue, for example, made it necessary to develop special microtomes to do this job. This may consist of a rotating circular knife with a delicate feed mechanism which is able to cut specimens as thin as 1/40 micron.

Sometimes it is undesirable or difficult to obtain a thin slice from the surface of a bulk material, for instance, a metal. In such cases, negative or positive surface replicas are used. A negative replica is made by

Two typical micrographs obtained with electron microscope. Cartridge steel, 60 kv—60,000 X. (left). Tobacco mosaic virus, 100 kv—200,000 X (right)

applying a solution of plastic or resin to the surface to be studied. After this film dries, it is removed from the surface and shadowed. A positive replica is made from a negative replica. Negative replicas may be polyvinyl alcohol in water, zapon acquanite A in amyl acetate, carboxymethyl cellulose in water, or molded polyethylene. Positive replicas may be formvar in ethylene dichloride, collodion in amyl acetate, or collodion.

Electron microscopy and electron diffraction are complementary tools of the modern research technician. Like X-ray diffraction, electron diffraction gives patterns which identify materials that are present. The North American Philips Company's microscope is designed to permit quick and easy changeover from electron microscopy to diffraction.

The Philips electron-optical system includes five magnetic lenses. The first acts as a condenser lens for illuminating the specimen, the second is an objective lens, the fifth one is a projector lens. The third and fourth lenses are energized alternatively and are designated as diffraction and intermediate lenses. The intermediate lens makes it possible to reach a very high total magnification with a microscope tube that is relatively short. By varying excitation of this lens the magnification can be varied continuously from 8,000 to 80,000 diameters with the entire area of the screen utilized. When the diffraction lens is in use, the magnification is smaller than that of the objective and projector together. This makes it possible to cover the range of 1,000 to 8,000 diameters, thereby linking up with the range of the optical microscope.

The excitation on the diffraction lens is adjusted to focus the image on the fluorescent screen.

Electrons in the electron microscope are emitted from a tungsten filament surrounded by a metal cap with an opening of about 1 mm through which the electrons can emerge. This assembly is at a high negative potential (40–100 kv) with respect to the grounded metal shield of the microscope tube. The electrons emerging through the opening in the cap are accelerated by the voltage difference. Due to the focusing action of the electric field, the electrons follow the axis of the tube in a narrow beam.

For visual work, the electron microscope has a fluorescent screen which is observed by the technician. Where desirable, photographs of the image may be made by insertion of a special camera into a compartment provided in the instrument. When the camera is in position, the electron beam falls directly on the photographic film. A 35 mm roll film is employed and forty exposures may be made with one loading. The camera serves for both microscopy and electron diffraction work.

Many specimen holders can be employed, inserting one after another at will. Changing specimens admits only a small quantity of air to the column and the vacuum is restored in about 30 seconds, ready for the next examination. The vacuum pump is not in operation when the microscope is being used so as to eliminate vibration. When photos are desired, it is easy to insert and remove the camera.

Generating Unit Placed in Service at Ridgeland Station

Commonwealth Edison Company's Ridgeland Station, which was completed only recently when the fourth big generating unit was put in commercial operation, will be viewed by AIEE members during the fall meeting in Chicago, October 11–15, 1954. Willis Gale, Commonwealth Chairman, announced that the new Allis-Chalmers 150,000-kw turbine was approved for service following several weeks of test operation.

The nameplate capacity of the station is now 600,000 kw, the equivalent of more than 800,000 hp. The station consumes an average of 6,000 tons of coal a day and its output of electricity is enough to serve a city of more than a million population. The plant, with its connecting transmission facilities, cost in excess of one-hundred million dollars.

The first generating unit went in service in 1950, the second in 1951, and the third in 1953, and at some later date if load conditions require, it is possible to expand the station.

The units use steam at 1,800 pounds per square inch and up to 1050 F. Ad-

Turbine room at Commonwealth Edison Company's Ridgeland Station where fourth generating unit has been put into service to bring the station capacity to 600,000 kw

vances in the design have permitted use of just 2 boilers for each of the first 2 units, and now only a single boiler for each of the 2 later units. The substantial progress in efficiency is shown by a comparison with 25 years ago, when a typical 100,000-kw unit had 6 boilers and utilized steam at 550 pounds pressure and 750 F. Also, units built 25 years ago required more than $1^1/_2$ pounds of coal to produce a kwhr of electricity, while the latest Ridgeland unit will need less than one pound per kwhr.

The most modern equipment for the reduction of fly ash has been installed, so that all but 0.5 per cent of the fly ash is eliminated. Each boiler has equipment to measure the density of the stack discharge. A continuous record is registered in the station control room so that the operator is immediately aware of any failure in the air cleaning equipment and can take steps to correct it.

The station has several 138,000-volt lines to tie the plant in with the transmission system which blankets Chicago and northern Illinois, as well as several 69,000-volt lines connecting to other parts of the system. Because Ridgeland Station contains the most modern generating equipment on the system it will operate at or near capacity 24 hours a day.

Ridgeland is the largest single project in the Commonwealth's 11-year one-billion-dollar construction, which was started at the end of World War II. From 1946 to date the system has added 1,134,000 kw of generating capacity and presently has under construction 491,000 kw. When the present program is completed the total capacity will be 3,913,000 kw, an increase of 71 per cent over 1945.

Line Converter Used in Relay of Television Broadcasts

At present, several different television standards are in regular use in Western Europe. They all have the same frame frequency of 25 complete pictures per second (two interlaced frames forming one complete picture), but one of the points in which they differ is the number of lines per frame. An exchange of television programs among the West-European countries is therefore possible only if there are means available for converting pictures of one number of lines into those of another. In the article, "A Line Converter for the International Exchange of Television Programmes," by J. Haanljes and Th. G. Schut, *Philips Technical Review*, May 1954, a description is given of the line converter which was used to convert the British (405-line) television signal into a 625-line signal for transmission in the Netherlands and Western Germany on the occasion of the Coronation in London in 1953. The apparatus was also capable of converting signals of the French standard (819 lines) into the 625-line system. The line converter uses a picture tube to produce an intermediate optical image of the incoming signal. The image is viewed by an image iconoscope which scans it in the 625-line system. The disturbing effects which occur during this process are dealt with, as well as the means for eliminating them. The latter include: the use of a long afterglow phosphor in the picture tube, spot-wobbling in the picture tube, clamping of the black level in the output signal at the beginning of each scanning line, and the equalization of the picture frequency of the 625-line system to that of the incoming signal (when the conditions are suitable). The picture screen has a diameter of 12 cm, and the long afterglow phosphor is willemite. The luminance reaches a maximum value of 5,000 unit. Its mean value is ample to ensure that the image iconoscope is almost free from spurious signals, and that the signal-to-noise ratio of the signal is only sightly diminished on passing through the line converter.

Giant Klystron Electron Tube Breaks "Electron Barrier"

The development of a powerful giant electron tube, known as a megawatt klystron, paves the way for radar's reaching far beyond present limits. The 8-foot tube, sponsored by the Air Research and Development Command (ARDC) and designed by Sperry Gyroscope Company, produces 4,000,000 watts of radar power—more than 250 times that developed in the radar that beamed pulses to the moon and back in 1946. The frequency of this power can be held 20 to 200 times closer than the frequency limits of radio or television transmitters. A prototype tube is now installed at the ARDC's Rome Air Development Center, Griffiss Air Force Base, N. Y.

In a klystron, an electron gun in the base of the tube shoots a stream of electrons through three hollow copper doughnuts, called rhumbatrons; and the power output of the tube depends on the number of electrons that can be forced through the holes. The quantity of electrons can be increased up to a certain amount, but beyond this point a barrier is encountered that causes the electrons to be thrown out of the beam and dissipated in other portions of the tube as heat, rather than as additional output power.

Eight-foot 4,000,000-watt klystron installed at Griffiss Air Force Base

Sperry engineers were able to shape a magnetic force that made it possible to concentrate more electrons into the beam and thus produce more power output. The new giant klystron is an illustration of how the focusing method breaks the "electron barrier" so as to permit the generation of millions of watts of power.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

The Decilog

To the Editor:

The article entitled "The Decilog: A Unit for Logarithmic Measurement" prompts me to bring to your attention the contents of a letter which I wrote, on March 5, to the AIEE Committee on Telegraph Systems. I quote:

"This is in reply to your letter of March 3, 1954, to members of the committee, enclosing material relating to the question of a new logarithmic unit and abbreviation for expressing ratios of quantities other than electric power, current, and voltage.

"Mr. Green presents a convincing story and argument, until he reaches the point where he proposes a name and an abbreviation. Permit me to comment on these two aspects.

"*Name.* The proposed term deci-log has much to commend it. It is just unfortunate that the scientific and engineering worlds both use the 'common' or Brigg logarithms *and* the 'natural' or Naperian logarithms. Therefore, in many fields, the proposed term might be considered imprecise and confusing.

"A more suitable term might be coined from the words deci-common-logarithm.

This could be DECOMLOG, which would be abbreviated to 'dcl' or, less precisely and more loosely, to 'dl.'

"*Abbreviation.* Use of the initial and final letters of a compound term, such as deci-log (*dg*), appears to be contrary to all scientific and engineering terminology and abbreviation practices. The accepted practice, throughout scientific and engineering fields, seems to be that the letters used designate: first, the multiple or submultiple; and, second, the basic unit *or* quantity. Examples are legion, so need not be cited.

"The abbreviation 'dl' is the only proper one for the proposed term 'deci-log.' The arguments advanced against it seem to be extremely weak, and rather farfetched, in view of the fact that we commonly use the small letter 'l' in printed literature for such quantities as length, lumens, liters, etc.

"Incidentally, the abbreviation 'dg' usually is listed as standing for 'deci-gram.' Such conflicts may be unavoidable, but should be carefully considered.

"*Alternatives.* Following the BEL and the NEPER, it would seem desirable to adopt the term BRIGG (deci-Brigg), except for the unfortunate conflict with the present db designating deci-Bel. Perhaps some other noted mathematician could be honored by having his name used to designate the new universal unit.

"Or the term 'deci-Brigg' could be abbreviated to 'dbr.' Perhaps this might be the most practical solution."

It would seem advisable to obtain much more widespread agreement on a suitable term, or "name," before attempting to include a definition thereof in the current revision of "American Standard Definitions of Electrical Terms" (ASA, *C-42*).

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Decibels and Decilogs

To the Editor:

Ever since the decibel was proposed under its original name, the transmission unit, there has been a difference of opinion as to its nature. This has again risen to an acute stage in connection with the current revision of definitions. During these almost 30 years, I have tried without success to understand the viewpoint of those who contend that the decibel is not a logarithm. It would be a great help in doing so if someone among those who are advocating a definition based on this concept would cite an example of something which he considers *is* a logarithm and point out exactly how it differs from the decibel.

The same considerations apply to the decilog, a definition of which has recently been approved[1] for inclusion in American Standards Association no. *C42*. It is defined as "a division of the logarithmic scale." It is not obvious to me what this is. If it is a logarithm, the definition would be simplified by calling it that. If it is not, there should be included an exact definition of what constitutes "a division of the logarithmic scale." The last sentence of the definition would be improved if it were made to read, "One decilog is therefore the logarithm of a ratio of $10^{0.1}$."

A more straightforward definition would be something like this: "The decilog is a logarithm which has been standardized for use as a secondary unit in expressing the magnitude of the logarithm, to any base, of any number or ratio. It is the logarithm of the number $10^{0.1}$, taken to the same base as the logarithm being expressed. The number of decilogs in the logarithm of any number is equal to ten times the logarithm to the base ten of the number."

R. V. L. HARTLEY (F'51)

(174 Summit Avenue, Summit, N. J.)

REFERENCE

1. The Decilog: A Unit for Logarithmic Measurement, **E. I. Green.** *Electrical Engineering*, vol. 73, July 1954, pp. 597–9.

NEW BOOKS

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

THE CATHODE RAY OSCILLOGRAPH IN INDUSTRY. By W. Wilson. Chapman and Hall Ltd., London, England, fourth edition, 1953. 273 pages, 8¾ by 5¾ inches, bound. 36*s*. Descriptions of components, kinds of tests, and applications of tests in electronics, engineering materials, and engine performance have been brought up to date in this revision, and the chapter on electron microscopes has been rewritten. Radiolocation is now treated in the body of the text and recent Swiss developments in the metal-tube instrument are recorded in the appendix.

DIE MESSWANDLER. By Rudolf Bauer. Springer-Verlag, Berlin, Germany, 1953. 313 pages, 9⅜ by 6⅜ inches, bound. DM 33. A comprehensive treatment of the basic principles, operation, applications, and testing of instrument transformers. It covers the characteristics, possibilities, and limitations of current and voltage transformers, analyzes the effects of overvoltages, transients, etc., and gives useful data for selection and design. Other specialised topics are considered in connection with the major subjects.

OPTICAL INSTRUMENTATION. Edited by George S. Monk and W. H. McCorkle. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., first edition, 1954. 262 pages, 9½ by 6¼ inches, bound. $3.75. The papers in this volume, based on reports written from 1943 to 1945, deal with problems of designing optical glasses resistant to effects of high-energy radiations. Part 1 discusses fundamental requirements and the way these were met. Part 2, the major part of the book, consists of condensed reports on typical instruments and on technical processes developed to meet the needs of the designers.

PHYSICS AND APPLICATIONS OF SECONDARY ELECTRON EMISSION. By H. Bruining. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., 1954. 178 pages, 8¾ by 5¼ inches, bound. $5. A survey of emission mainly from the entrance side of different kinds of substances in the solid state. The first part covers physical aspects—methods of determining and measuring, the emission yield of metals and metal compounds, and the mechanism of the phenomenon. The second part deals with applications—amplification with electron multipliers, elimination of disturbing effects, and storage devices. Bibliographies are provided.

PRINCIPLES AND PRACTICES OF TELECASTING OPERATIONS. By Harold E. Ennes. Howard W. Sams and Company, Inc., 2201 East 46th Street, Indianapolis 5, Ind., first edition, 1953. 596 pages, 9¼ by 6¼ inches, bound. $7.95. A detailed study of technical equipment, written for technicians, producers, and directors. It begins with a review of basic theory, then takes up each component from the camera lens to the transmitter antenna. Following this are chapters on setting up, operating, and maintaining studio and field equipment, and on transmitter circuits.

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RADIO RECEIVER DESIGN. Part 1: Radio-Frequency Amplification and Detection. By K. R. Sturley. John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y., second edition revised, 1953. 667 pages, 8½ by 5½ inches, bound. $10. Fundamentals are presented by a detailed examination of the receiver, stage by stage, starting from the aerial. This volume, the first of two, ends at the detector stage. The revision consists of clarifying some sections and adding new material, for example, on the noise factor, on self-capacitance and mutual inductance of coils, and on crystal-coupled i-f transformers. References following each chapter have been brought up to date.

SCINTILLATION COUNTERS. By J. B. Birks. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., 1953. 148 pages, 8½ by 5½ inches, bound. $4.50. This monograph consists of a historical introduction, enumeration of factors influencing the performance of the instrument, consideration of photomultiplier characteristics, discussion of pulse-height and time resolution, treatment of inorganic phosphors, photo-fluorescence, and organic crystalline phosphors, and a review of the author's photon exchange theory of fluorescence. The two last chapters cover the interpretation of properties of plastic and liquid phosphors, and major applications of the scintillation counter. There is a bibliography.

TECHNISCHE KOMPOSITIONSLEHRE. By Fritz Kesselring. Springer-Verlag, Berlin, Germany, 1954. 394 pages, 9½ by 6½ inches, bound. DM 39. This volume deals with what might be called the "science of engineering creativeness." Intended for development and design engineers, the book presents the human, scientific, and economic interrelationship with which creative engineers should be familiar in addition to their purely technical knowledge; Part 2 covers the fundamental aspects of invention, design, and form from a practical standpoint.

THEORIE DES FONCTIONS ALEATOIRES. By A. Blanc-Lapierre and Robert Fortet. Masson et Cie, Paris, France, 1953. 693 pages, 9¼ by 6½ inches, bound. Ffrs. 6,500. An extensive development of the theory of random functions, rigorously handled by the mathematician, but in such a way as to facilitate a physical interpretation of the mathematical theory. In the latter part of the book sections are devoted to detailed accounts of two typical applications: to the problem of noise in telecommunications; and to the statistical and dynamic approach to turbulence problems.

RELAXATION METHODS. By D. N. de G. Allen. McGraw-Hill Book Company, Inc., 330 West 42d Street, New York 36, N. Y., 1954. 257 pages, 9¼ by 6½ inches, bound. $7.50. An introductory text for students or practicing engineers that takes up the process of solution in detail for various typical applications chiefly in the fields of elasticity, hydrodynamics, electricity, and magnetism. Emphasis is placed on the essential arithmetical processes and techniques. Mathematical theory is kept to a minimum.

TABLE OF SECANTS AND COSECANTS TO NINE SIGNIFICANT FIGURES AT HUNDREDTHS OF A DEGREE. (Applied Mathematics Series, number 40). National Bureau of Standards. Superintendent of Documents, Government Printing Office, Washington 25, D. C., 1954. 46 pages, 10½ by 7½ inches, paper. $0.35. A companion volume to the previously published table of sines and cosines for decimal divisions of degrees. The customary explanatory introduction precedes the table.